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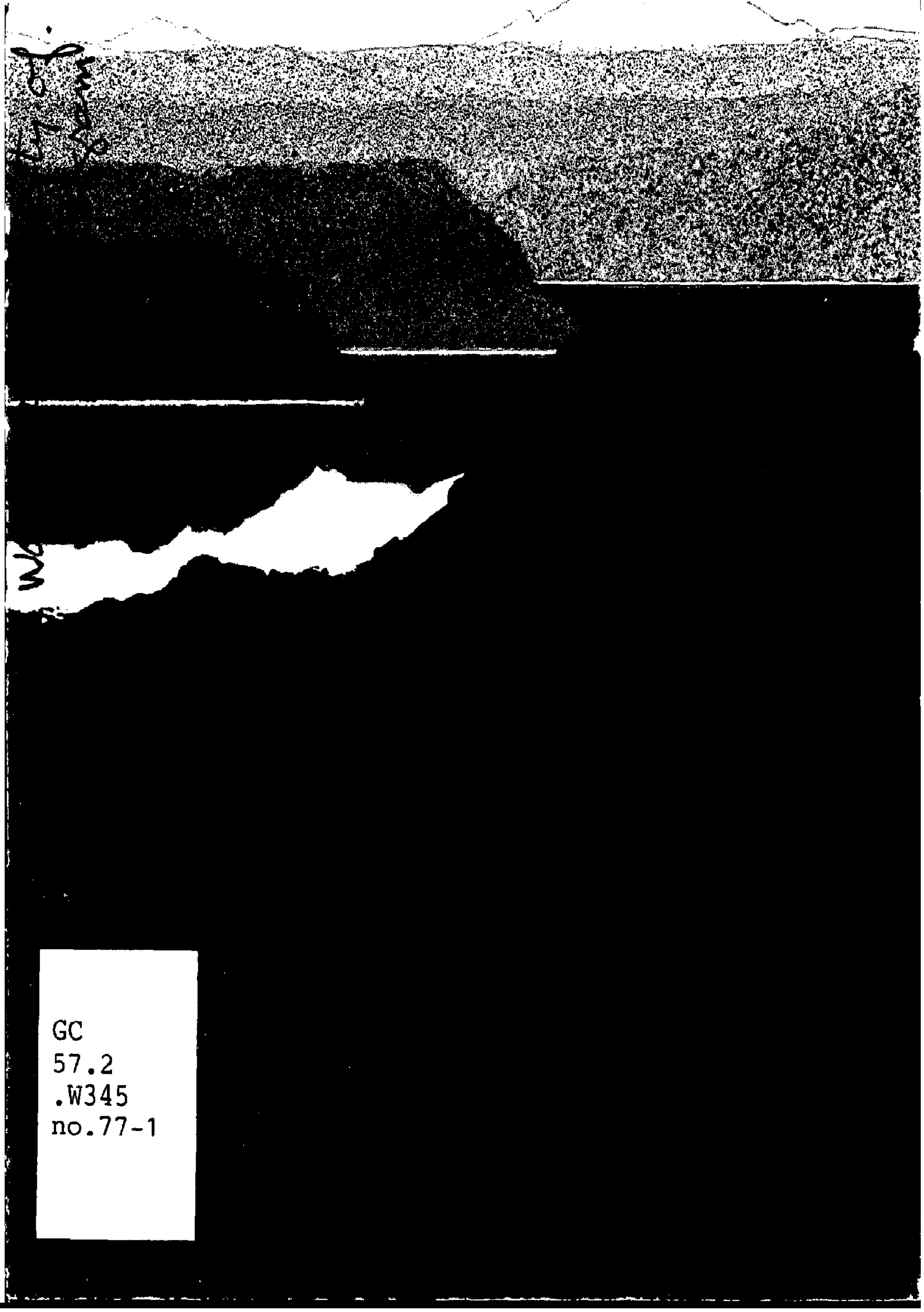
THE USE, STUDY AND MANAGEMENT OF PUGET SOUND



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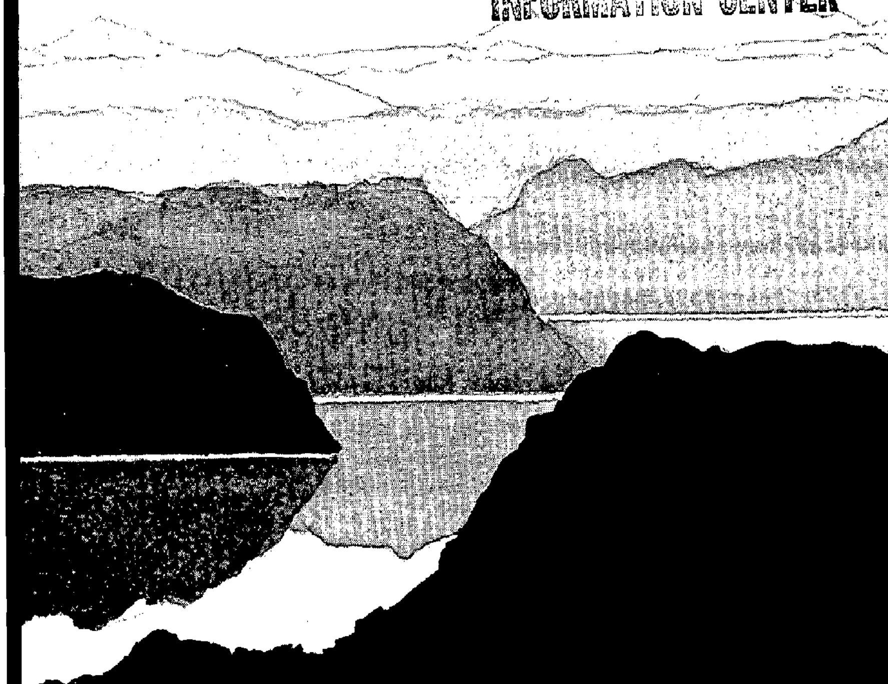
THE USE, STUDY AND MANAGEMENT OF PUGET SOUND

A SYMPOSIUM



PROCEEDINGS
March 23–25, 1977
A Washington Sea Grant Publication
University of Washington • Seattle

Washington, University of. Sea Grant Program

THE USE, STUDY, AND MANAGEMENT OF PUGET SOUND

Symposium Sponsors	Division of Marine Resources University of Washington
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	Peter Machno Seattle METRO

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Special thanks go to each of the panel members of this symposium for the time and effort expended in participating in this symposium. Our thanks also to the attendees, whose input during the discussion and question periods added substantially to the success of the symposium.

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FOREWORD

The past few years have seen significant changes in public philosophy toward man's use of the earth's resources. No longer does man consider himself independent of his resources. And he is increasingly aware of the need to protect and conserve natural resources as well as to use them wisely. His attempts to assure the preservation of his resources as well as set patterns for their rational use have led to legislation that regulates those uses. These regulations were written both as guides for those wishing to conform and as restrictive covenants for those less sympathetic toward protecting nature.

But since man is sometimes nearsighted in establishing the routes to achieve his goals, it is good practice to review those routes occasionally to see if indeed the correct track is being followed.

This symposium--*The Use, Study and Management of Puget Sound*--is an example of this type of hindsight. Here specific questions have been posed regarding the uses of Puget Sound, the regulations that govern these uses, and the effects of those policies on the environment and its users. Varied viewpoints have been presented to generate a realistic perspective.

It is our hope that the efforts of those contributing to this symposium, as recorded here, will be considered by readers responsible for the fate of Puget Sound and be used to good advantage.

Alyn C. Duxbury

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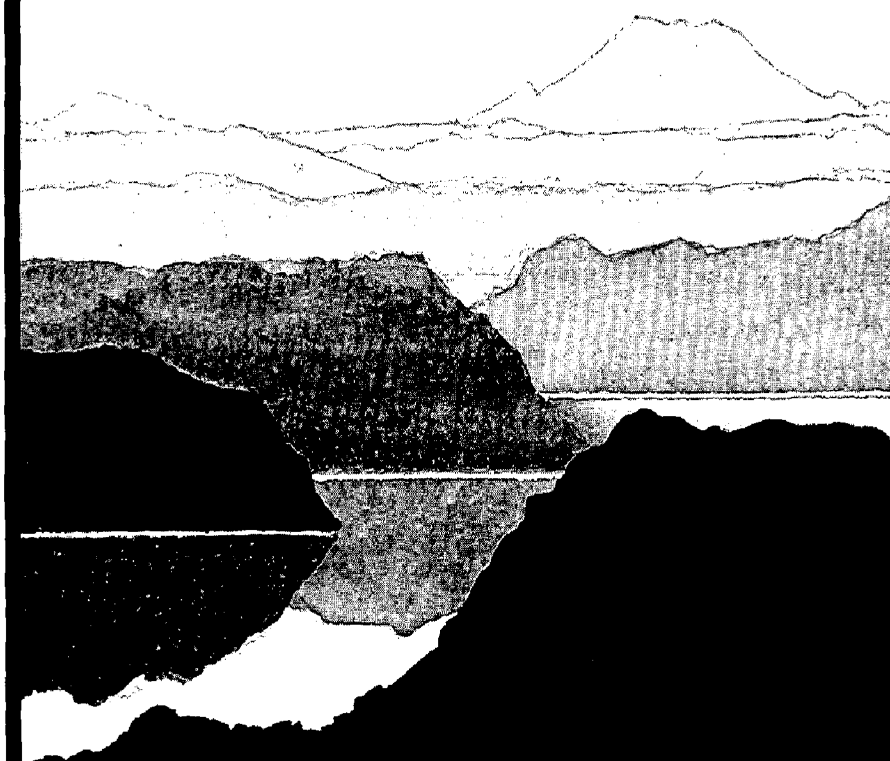

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OPENING REMARKS

Capt. Griffith C. Evans, Jr., USN (Ret.)
Trustee, Oceanographic Institute of Washington

This is in no way to be construed as a complaint, but in reviewing the agenda for this symposium, the title could easily be reduced to "The Management of Puget Sound." Perhaps this assertion will be made clear shortly.

Were we to go back in time to prehistory and come up through history until, say three decades ago, the symposium title would not only be more logical, but the sequence of words in the title would be an accurate description of man's relation to this mentally and spiritually preoccupying body of water. Use obviously came first. Early man used Puget Sound as a source of food, a medium for transportation, and, quite probably, a receptacle for waste disposal. It couldn't have taken long thereafter for some sort of study to have begun: The measurement of the rise and fall of the tide, and its intervals, both daily and monthly; the best times and places for harvesting shellfish and fish; the discovery and word passing of locations of "safe havens" when weather threatened those who were water-borne, etc.

This, then, was essentially the state of the art from the time of habitation of our first native Americans until relatively recently. Puget Sound remained, and still does remain a body of water used for the harvest of seafood, waste disposal and transportation. We could add "recreation" to these uses as spin-offs from transportation, and from man's earliest time there must have been that use of "aesthetics," as few men could fail to find exhilaration or serenity or awe in beholding the special beauty of this water environment.

Study progressed at approximately the same pace as use. Systematic bathymetry began with the arrival of the first European explorers and is increasing constantly to cope with the requirements of both users and managers. Scientific research into fisheries, oceanography, the atmosphere, biology, etc., was begun, but prior to World War II such studies were undertaken primarily by individual academicians and their disciples, who were investigating their own topics of interest and concern. These of course, were useful, imaginative and often of great significance, but they were essentially random studies--rarely coordinated with other research--and rarely were the results of these works known except to readers of technical and scientific publications.

The quantum leap in studying Puget Sound really happened after World War II. In the 1940-41 period, scientists in America suggested and developed coordinated undertakings to help the country prepare for a war that appeared to be, and in the end was inevitable. After the war our national government considered scientific achievement so desirable--as did many of the scientists themselves--that federal monies were made available for both pure and applied research, and among many other results, systematic and coordinated study of Puget Sound began emerging.

These studies plus the acceleration of uses, and some of these uses had adverse effects on others, inevitably led to management. This latter function is still fragmented, which means uses and studies often are also fragmented as each is more and more subservient to management. In fact, management increasingly dominates both use and study. With various federal agencies having spheres of jurisdiction, sometimes overlapping, and with state and local governmental agencies in the same boat it is no small wonder that confusion often exists. Of greater wonder is that things work at all, and sometimes are highly effective even if the results of applied efforts are occasionally astonishing.

I can think of no better way to open a symposium such as this than having our attention directed to the management of Puget Sound by our keynote speaker. His position in state government is elective; namely he is the State Commissioner of Public Lands, and in that capacity is also Director of the State's Department of Natural Resources. I don't know how many times he has been re-elected by the people of our state, but I understand that when he first started the only environmental impact statement heard of until then was the one Moses had to file to have the seas parted so he could lead his tribes into Israel. Be that as it may, those of us who have worked with him have learned to respect and appreciate his interest in, and concern for Puget Sound. It is an honor and a pleasure to introduce the Commissioner of Public Lands and Director, State of Washington Department of Natural Resources, the Honorable Bert Cole.

PUGET SOUND: A PUBLIC NATURAL RESOURCE

Bert L. Cole
Commissioner of Public Lands
State of Washington

INTRODUCTION

The state of Washington is blessed with one of the most unique marine environments in the world. Puget Sound is noted for its significance as a natural deep water port, as well as for its fisheries and aquaculture potential, its natural beauty, and its scientific and recreational values.

The Puget Sound Basin contains approximately 90% of the state's population. So the future protection and proper management of the marine waters, bedlands, and shorelines of Puget Sound are vital. They depend on coordinated planning by public agencies. They depend on the sharing of knowledge and cooperation between government, academia, industry and the public. To that end, the people who put together today's symposium are to be commended.

After 20 years as a state-elected official, I believe strongly that we cannot afford to be provincial in our approach to the use and protection of our natural resources. In this case, I believe that individual and local desires relating to Puget Sound must be considered by decision makers in the context of the present and future needs of larger communities . . . including the state, the nation, and the world.

Directions for the management of Puget Sound began with our state's Enabling Act and the Constitution and have evolved over the years through legislation and administrative policies. In general, our mandate from the legislature is to manage Puget Sound for the maximum long-term public benefit. In order to accommodate various public needs, while protecting the resource itself, a multiple use management approach is essential.

MULTIPLE USE

For the Department of Natural Resources, which I administer, the concept of multiple use is the guiding principle for the management of more than two million acres of aquatic lands in Washington. The DNR is the largest marine land manager in the state. It is responsible for managing 1,300 miles of first and second class tidelands, 6,700 acres of harbor areas and nearly 2,000 square miles of bedlands. In a nutshell, multiple use or shared use means that several uses or activities can take place on the same piece of real estate. In most cases, the concept calls for identification of the primary use of the land, but provides for compatible secondary uses.

The benefits of such an approach are obvious. Puget Sound has a tremendous value to citizens of Washington, the nation, and the world as a seafood producer, as an area for shipping and international trade, as a recreation and tourist attraction, as a sport and commercial fishing area, as well as wildlife habitat and fish spawning and nursery ground. With careful planning, many of these uses can occur simultaneously or sequentially in a single area.

Certain activities can only occur on a planned rotation basis. For instance, structures such as piers, log rafts, and oyster rafts obstruct the use of the land and water column for other activities such as boating, fishing, etc. These obstructions are not permanent, so leasing provisions are established that allow periodic rotation of uses as demands change.

The DNR Management Plan for state land in Puget Sound includes policies and guidelines for the following:

navigation and commerce

public use

food, mineral and chemical production

protection of the natural marine environment

uses by abutting upland owners

revenue production

Commerce and Navigation

Today, 185,000 jobs in Washington depend on international trade. There are 21 states in the nation with a greater population than the state of Washington, but only 5 with a higher volume of trade. Washington State has nearly twice the per capita value of waterborne foreign trade to that of Oregon and California, and three times that of the nation as a whole. Of the entire United States' foreign trade with the Pacific Rim countries, we account for nearly 9% of exports and 13% of imports.

The economic future of the state, then, is closely bound to expansion of trade. We must consider commerce and navigation as one of the most important uses of Puget Sound for the future.

First class tidelands and harbor areas can best accommodate commercial activities. They are primarily useful for marine development, water dependent industry and commerce, boat repair and manufacture, and log storage.

Harbor areas are established by the Harbor Line Commission under provisions of Article XV of the State Constitution. According to the Constitution, these areas are established in front of incorporated cities and towns and "shall be forever reserved for landings, wharves, streets and other conveniences of navigation and commerce." Harbor areas are very important to the economic position of the state, as the interface of international shipping activities between the U.S. and the Pacific Rim. The establishment of a harbor area precludes the use of the submerged land within the inner and outer harbor lines for other than piers, wharfs and aids to navigation except on an interim basis.

Industrial uses are best concentrated and not allowed to disperse throughout the shoreline area. Full utilization of harbor areas and state-owned first class tideland is important if a greater portion of the shoreline is to be used for recreation or is to be maintained in a natural shoreline condition.

Public Use (Recreation)

Public recreation is another important and highly valued use of Puget Sound. Approximately 60% of the tidelands of Puget Sound are in private ownership. Forty percent are publicly owned and managed by the Department of Natural Resources. Public tidelands have been generally indistinguishable from private tidelands. To correct the situation, the DNR is marking selected state-owned tidelands for public use. This program is designed to provide access for the boating public to public property, while seeking to eliminate trespass.

Marking the beaches will allow for intensive management of shellfish resources and litter control, while alleviating the congestion and overuse of the few public beaches now available.

Most public beaches being developed are accessible only from the water. In order to make more beaches available to non-boaters, joint government efforts will be required to acquire uplands near population centers.

Food, Mineral and Chemical Production

It is a policy of the State Department of Natural Resources to provide for the production of food, minerals and chemicals on marine lands, with preference given to renewable resource activities. Tidelands and beds of navigable waters, especially valuable for aquaculture, are and will be so designated, and protected from conflicting uses. We will continue to provide information to encourage commercial aquacultural activity to expand into proper locations.

Traditional commercial fishing areas must be protected from competing uses that create obstructions. Whenever structures are used for aquaculture on the beds of navigable waters, they must be located in a way that lessens interference with navigation, fishing and the view.

Inventories on marine lands will be conducted as to the location of significant deposits of minerals and aggregates, and a determination made about the significance to the state of such deposits.

Seaweed farming, funded partly by the Washington Sea Grant program this year, will be tended in the Puget Sound by the DNR. The seaweed, *Iridaea cordata*, yields 50% of its weight when dried as the colloidal substance, carrageenan. The seaweed will be grown from spores deposited naturally on nets anchored in existing seaweed beds.

The nets can be pulled up, harvested two or three times a year, and put back again to continue growing. If the experiment is a success, it will help show that commercial cultivation of seaweed has an important future in Puget Sound.

Protection of the Natural Marine Environment

Puget Sound is one of the deepest and cleanest saltwater basins in the United States. Recognizing the importance of protecting areas of natural marine environment for ecological, educational and scientific purposes, aquatic land reserves on Puget Sound have been established. The DNR will control their use through protective management policies and surveillance. In certain cases these areas may be leased or assigned to another agency for management as reserves or protective aquatic lands.

Uses by Abutting Upland Owners

The state recognizes the need to provide certain tidelands and bedlands for use by abutting upland owners and to consider certain riparian interests in the management of marine lands. When tidelands are leased to someone other than the abutting upland owner, such leases provide for the abutting owner to reach the beds of navigable waters.

Second class tidelands not allocated for public use may be made available for lease to the abutting upland owner without providing for public use. In those cases where tidelands are managed for public use, the rights of private upland owners abutting public use tidelands are recognized by marking of the intervening property lines and posting of the tidal tract.

Anchorage areas on the beds of navigable waters are designated for use by upland owners for mooring boats.

Revenue Production

Under the multiple use concept, whenever the availability of the public lands is reduced due to private use, the public must be compensated. The value of state-managed tidelands and beds of navigable waters to the general public is recognized by charging competing lessees the full market price for the land. Total withdrawal for private use requires a full rental payment.

When the effects of marine uses have an adverse impact on public land, a value is placed on the loss or impact and charged to the user.

Revenues made available from leasing of marine lands are used for marine land management programs that are of direct benefit to the public.

First class tidelands and harbor areas in Puget Sound, unless withdrawn by the Commissioner of Public Lands as recreational use property, are managed to produce revenue and service to the public.

Lease rates may be reduced for up to 5 years--an incentive when lessees are involved in research or development work which is in the public interest.

CURRENT STATE LEGISLATION

Senate Bill 2450, which reviews laws dealing with aquatic lands, was reintroduced in the current session of the legislature. The purpose of the bill is to clearly state the legislative policy regarding publicly owned aquatic lands, to amend existing laws to provide consistency with that policy, and to adopt certain new provisions needed to carry out the declared policy.

The policy provides for:

1. Retention of title by the public (no sale except to government).
2. Leasing for private use and government use which does not meet the public use definition.
3. Free public use of land not leased.
4. Protection from unauthorized uses.
5. Acquisition of replacement land for any that is sold.
6. Management of these public lands for the benefit of all the people of the state as a public trust.
7. Management to produce the maximum long-term public benefit.
8. Statewide public interest given priority over local interests.
9. Land classification based on ecological, social, economic, and other values.
10. Payment of full fair market value for removal of any materials from the land.

Another bill (SB 2448) deals with harbor areas. It completes the review of the state aquatic land laws called for by various resolutions of the legislature. It authorizes the DNR to enter into agreements with local government for waterway administration, to authorize temporary occupation of waterways, to initiate vacation of waterways.

According to the bill, harbor area improvements are to be rent free so long as the leasehold is unbroken. Harbor area valuation is to be based on fair market value. State-owned waterway borders are to be administered by the state rather than the port district.

CONCLUSION

In managing Puget Sound for maximum long-term public benefit, there are naturally many things to consider: The requirements of commerce and navigation; the rights of private property owners; the needs of ports, cities, and commercial fisheries; the desires of boaters, swimmers, sport fishermen, and educators. Accordingly, in the state's plan for the future, vast areas of Puget Sound are allocated for unobstructed multiple use.

The use and protection of Puget Sound require an evaluation of the public interest. They require vigorous efforts in research and public information. For the common good, individuals must set aside their particular desires, and government agencies must work together.

What is required most of all, is dedication by each of us to the principles of careful stewardship. For, as another Puget Sounder, Chief Seattle, said more than 100 years ago . . . "This we know. All things are connected like the blood that unites one family. This we know. The earth does not belong to man; man belongs to the earth."

SHORELINES AND THE CITIZEN

Nancy Thomas
Washington Environmental Council

Good afternoon. It's a pleasure for a mere environmentalist to be in the same room with so much accumulated knowledge about marine ecosystems.

As a born opportunist, I can hardly wait to get an attendance list for this symposium--because collectively you people probably know just about everything I've needed to lay hands on over the past 4 years. You'll be hearing from me!

I'm supposed to be here today to represent the views of the Washington Environmental Council and to some extent I'll do that. But most of what I'm going to say comes from my personal experience with the subject matter of this symposium.

What is an environmentalist anyway? I say we're all environmentalists. We all get mad when the air we're breathing gives us a sinus headache. We all turn on the kitchen tap with a touching faith that potable water will flow therefrom. We all wrinkle our noses and tell Junior for the third time to get away from the television and for heaven sake take out the garbage! That's environmentalism--being concerned about the world around us.

We environmental <u>activists</u> simply carry that concern one step farther. We are just people who are sufficiently concerned about both the present and future of the world we live in to give of our time and our money and to sally forth into the political arena, there to suffer bloody noses, bruised egos and occasional triumphs.

The history of the Washington Environmental Council has been closely related to the history of water management programs. As an organization, we were born in the aftermath of the famous "Wild Rivers Bill" of 1967. So we've been around quite a while and we've learned a bit, and got to know a few people.

I've written these comments in advance without the benefit of hearing yesterday's speakers. But I'd like to give my own answer to the question: "Are federal, state and local laws, regulations and guidelines doing the job of conserving the marine environment?"

I say "No, they're not" and, until they give me the hook I'd like to tell you why I feel that way.

Political decisions are made by three groups. In descending order of importance, they are

elected officials

professional planners

citizens' committees

Now I--as a citizen environmentalist--have worked on the political end of resource management for roughly 12 years, intensively for 7 years. I know personally most of the politicians and planners who spoke yesterday. I know personally most of tomorrow's speakers. Today seems to be "technology day." According to the advance program, 19 individuals authored 11 papers to be presented today— papers containing the kinds of information essential to managing a marine resource of great public value. How many of these information sources do I know personally? After 12 years of activism? Not one.

Between you and me, between you and local planners, between you and the elected officials who decide the fate of Puget Sound yawns a chasm that makes Grand Canyon look like the Montlake Cut. You have the knowledge. But they make the decisions.

They don't know what you're talking about. To some extent, they don't even know you exist. And what is worse the majority don't <u>want</u> to know you exist.

The desire of Joe Bigbucks to build an overwater office building or a private port next to the Nisqually Delta they do understand. They meet Joe regularly at Rotary luncheons. Joe's a pillar of the local Chamber of Commerce, and he's also a big campaign contributor. Joe is a personal friend.

So what happens when you march in to tell the legislative body Joe's project should not be built because it will lead to trapping of pollutants by tidal eddies with resulting negative impacts on phytoplankton production and/or benthic infauna? Well, I'll tell you what happens. If it's a good day, they may just say "Thank you, Dr. Jones" and proceed to grant the permit. It it's a bad day and if you work for a public agency, they may try to get you fired for such presumption. I've actually seen that effort made.

And in some ways the situation is getting worse. It's the fad this year to attack "the bureaucracy" and the "regulatory agencies" as though they were some hydra-headed abstract monsters, rather than groups of often dedicated individuals trying to carry out a legislative mandate for a livable environment.

There is, unfortunately, an element of truth to accusations of over-regulation. But the blame for rules laid upon rules must be widely spread. Quite often it <u>is</u> a regulatory agency which drafted the regs. At other times--as with Washington's Forest Practices Act--the rules are actually written by the industry being regulated. Still they complain. And then we come to the regulations most directly affecting Puget Sound, the local Shoreline Master Programs. And they have been drafted by urban planners and by citizens' committees.

As a member of two such committees, I can tell you that the motto among the well-meaning environmentalists and citizens at large is "when you don't really have the data to back up your concern you bracket the problem with four airtight regulations and demand an EIS!" Well, if you have the votes, that solves the problem temporarily, but it doesn't make any friends and it makes a large and vulnerable target to shoot at when the master program goes before the local legislative body.

So how do we bridge this chasm? How do we get the technical information you possess into the hands of those our society selects to make policy judgments, in this instance the average citizen? That's not a rhetorical question, friends. I'm not going to supply the answer in the next sentence because I don't have the answer.

The two citizens' master program committees on which I served, one city, one county, very nearly represented two extremes. On one, the local planners wanted to be the only source of information. Requests for field trips were rejected. Requests, indeed demands, for expert advice were refused until the master program was virtually complete. Then the committee was given a bus tour of the port and a short ride on the fireboat. Field trips for the record. A representative of the State Department of Fisheries came in and supported the minority's viewpoint with data. But nothing was changed. A representative of the Corps of Engineers declined to appear and failed to send promised literature. That is the full extent of expertise represented in the shoreline master program of a metropolitan area with a major river system emptying into its port. That's one way the uses of Puget Sound are really planned.

Things were somewhat different on the county master program committee. There, neither staff nor development interests seemed to feel threatened by technical input, though citizens had to do some nagging, both of planners and of agencies. Two federal and four state agencies sent representatives to answer questions or advise subcommittees. Major industries also supplied research personnel.

When we combined the professional advice on some subjects with the old faithful "when in doubt bracket your target" technique, we ended up with what one resource agency noted was possibly the longest master program produced in the state, but also one of the best.

Well, as you can imagine, we felt pretty good about that. So much so that even after 2 years of work some of us masochists asked to be appointed to the master program continuing review committee--and we were--and guess who's on there with us? A number of people who had permit applications rejected and who therefore have decided to solve those little problems by rewriting the master programs.

So let me tell you this. One, being an environmentalist or a citizen at large on one of those committees is not fun. It's hard work; it's often carried out in a hostile atmosphere, and it can only be done by people who really care about the world they live in. Especially about Puget Sound. Two, as long as they're willing to be up there on the political firing line, they deserve maximum support from the scientific community.

What little support we got, we begged for--as on our county committee. Now how did that come about? I'm no scientist, but I can read a little.

I can read in Section 2 of the Shoreline Management Act that the legislature asserted: "a clear and urgent demand for a planned, rational and concerted effort, jointly performed by federal, state, and local governments, to prevent the inherent harm in an uncoordinated and piecemeal development of the state's shorelines."

In Sections 10 and 13, I read further invocations to interagency consultation and cooperation.

Section 3 of the State Environmental Policy Act directs consultation with and comments of "any public agency which has jurisdiction by law or special expertise with respect to any environmental impact involved."

Public Law 92-583, the Federal Coastal Zone Management Act, is perhaps most explicit of all when in Section 303, "Declaration of Policy," it says: "The Congress finds and declares it is the national policy . . . (d) to encourage the participation of the public, of federal, state and local governments and of regional agencies in the development of coastal zone management programs. With respect to implementation of such management programs, it is the national policy to encourage cooperation among the various state and regional agencies including establishment of interstate and regional agreements, cooperative procedures, and joint action, particularly regarding environmental problems."

Ah, such golden eloquence. Such high hopes it gave us all. But it never happened. At least it never happened down at that forgotten level where we the citizens were making basic policy.

Why did it fail at that level? Well, that is partly a rhetorical question because I do have a partial answer. At least it's the answer DOE and other agencies gave me. It's a two-part answer and half of it even makes sense.

The first part is that agencies didn't need to participate in master program drafting because they could review the completed program before final state acceptance. That statement could be subtitled, "The Naivete of the Bureaucracy." It overlooked the fact that before master programs ever went to the state, they were approved, after formal public hearings, by local legislative bodies. Hell hath no fury like an elected official put down by a bureaucrat.

The second part--the part that does make some sense--is that with 39 counties and about 75 cities each preparing master programs, no agency could spare the staff to participate in all this fragmented planning. Some did answer the anguished wails of beleagured conservationists and sincerely interested planners. Others metaphorically plugged their ears and issued an across-the-board refusal.

I think no one disputes that--from the point of view of good resource management, the Shoreline Act worked better for the year or more in which it was administered by all jurisdictions with consistency under the state guidelines.

Obviously, neither Puget Sound nor the rivers that nourish it respect arbitrary political boundaries. From the resource management viewpoint it is ironic that in fact rivers were quite often selected to be political boundaries. For example, Pierce, Lewis, and Thurston Counties all are bounded by some segments of the Nisqually River. Jurisdiction also is shared with the federal government: a national park, national forest, national wildlife refuge and Fort Lewis. And the Nisqually Indian reservation borders the river, too. Several smaller towns, such as Eatonville and Roy, have jurisdiction on important tributaries. So with that kind of fragmented political responsibility, just how do you manage the resource? Cooperatively? A representative of Roy and one from DuPont did work on the Pierce County committee. Fort Lewis was represented for the first few months. The Nisquallies attended the first meeting. Lewis and Thurston Counties were never even heard from. In fact, contact among conservationists on the various committees often was the only source of information on what was being planned for the other bank of the river. Even the planners themselves didn't seem to know or feel the need to know, although there were and still are regular meetings of planners arranged by the Department of Ecology.

And that is the situation on just one tributary to the great inland sea I shall call Puget Sound. Let me make it clear right now that I don't propose to nitpick about Admiralty Inlet, Hood Canal, Washington Sound, the Strait of Georgia, the Strait of Juan de Fuca. In fact I think I will just call it the inland sea, and in those words, include inland marine waters bordered by 12 Washington counties and by more cities and towns than I care to enumerate. In some of those 12 counties all or some towns allowed the county to include them in its master program. But many cities and towns chose to go it alone and they included, as you might have guessed, most of the cities on marine waters.

Well, as I've suggested in describing my own communities' master program travails, the great majority of these programs are almost straight-out land use plans. They call attention to--and sometimes resolve--problems of shoreline sprawl, of unrestricted overwater development, of the filling of estuaries and the dredging of sandspits, of permissive dedication of urban shoreline to non-water-related uses. They do tell the public--those who want to listen--that the waters of the state belong to the people of the state; that their permission through their elected government, is needed before those waters may be dedicated to private use. And even though the private waterfront owner is much more alert to this and much more defensive of his perceived interests than is the general public, we will never go back to the days before the Shoreline Management Act, to the days before Wilbour v. Gallagher (the Lake Chelan case). Too many people know now the richness of their aquatic heritage ever to go back that far.

This is the two-fold success of the Shoreline Management Act--that people can know what is theirs--and that governments did draw shoreline plans which recognize a difference between upland and shoreline. No longer--as Professor Ralph Johnson once put it--does conventional zoning simply proceed to the water's edge and plunge like lemmings into the sea.

But there is still a void in shoreline planning--recognized if not acknowledged by everyone involved. In the context of this symposium, let's call that void the inland sea itself. Almost every master program, couched in confident language regarding upland activities, comes to an uneasy halt at the mean higher high water line. After testing the water and finding it chilly, the programs tiptoe around and eventually discover a face-saving device: the question that must be answered to the examiner's satisfaction before a permit may be issued.

This is not necessarily a bad idea. If the permit issuing body is truly concerned about resource protection, the data required of the applicant may add significantly to knowledge of site specific baseline conditions, and may in the very process of compilation lead to modifications in the project. Sometimes a would-be developer sees outright that his project is no-go; sometimes he finds an opportunity for mitigation of environmental harm.

But the fact remains that his approach is widely used <u>because</u> the drafters of plans did not know what lay beyond mean higher high water in <u>their</u> own jurisdiction and hence did not know what kind of value to place upon aquatic land and upon marine resources.

So we have two interesting conditions: first a form of willingness by planning bodies to admit they lack expertise, and second, lovely, lovely money to implement the state's Coastal Zone Management Plan.

Taken together and given a good solid shove by you scientists and by us environmentalists, they just might add up to a second chance--a chance to manage the inland sea and its tributaries as what they are: a single integral organism, and a resource so valuable we have not and perhaps cannot put a true value on it. (To our shame, we haven't really tried, but that's another dissertation in itself.)

The conservation movement in this state has always viewed the management of marine resources as a state, regional, and federal issue because we recognize the artificiality of arbitrary political boundaries. When developers complain about inconsistency among local master programs, I love to tell them: "Well, you should have supported our Initiative #43, then." For those of you who've come to Washington since 1972, the Washington Environmental Council in 1970 sponsored an initiative to the legislature, Initiative #43, which, after input from regional citizens' councils, would have placed shoreline management at the state level. The legislature, however, chose to write a combined state-local government alternative and both went on the ballot in 1972. Due to a curious quirk in Washington's election, the voter in this instance gets a double dip. He can vote for or against shoreline legislation and then, even if he voted against the entire concept, he can choose his preference between the initiative and the alternative.

So, among opponents to <u>any</u> shoreline legislation, the word was out: "Vote 'No' <u>and</u> vote for Alternative #43B just in case." Thus, between the nay-sayers and the genuine proponents of local jurisdiction the present Shoreline Management Act emerged as sort of a breech birth, but here it is and it's all we had to work with until our state program was accepted as meeting the requirements of the federal Coastal Zone Management Act.

A funny thing happened on the way to acceptance. The federal act with Senator Magnuson as prime sponsor, was signed into law just a few days before our initiative-alternative referendum, just too late to affect the outcome. And it was written with a strong element of state jurisdiction--and, coincidentally of course, both of our proposed laws seemed to be consistent, though the alternative just barely made it. Then, over the next few years while the federal government was writing strong implementing regulations for CZMA, our legislature was systematically nibbling away at the Shoreline Management Act, endangering its consistency with the federal law.

In the last months before final acceptance, a national controversy raged over Washington's plan, and it was fingernail biting time for some of us. Because acceptance meant federal money for implementation, money to local governments which they wouldn't turn down, money to the state for aquatic management and baseline studies. Without those dollars, shoreline planning hung in the balance.

The federal government had a lot at stake, too. Only 2 states, Washington and Maine, were ready for program certification and Maine's governor had abruptly repudiated his state's plan. If CZMA were to remain a viable federal statute, some state had to be accepted.

Don't ever doubt that a camel <u>can</u> be shoved through the eye of a needle!

I hope you'll forgive that little digression into history. But it helps explain <u>why</u> we are--on the one hand confronting a disparate, often conflicting bundle of local master programs and on the other hand looking at possible salvation-- salvation in the form of federal funding of the studies needed to plan the management of the inland sea.

As you know, the Department of Ecology presently has an aquatic management study under way. I don't know precisely what to expect from this study, but as a citizen, a conservationist and a shoreline committee member, I know what I need.

Overall, I need a management philosophy that does treat the inland sea as a single unit. Under our present system, this would require every jurisdiction to accept uniform guidelines. And the only way this can be made acceptable is to back those guidelines with hard data. Any number of planners would like to get the monkey of aquatic management off their back <u>if</u> they can convince local legislative bodies that uniform guidelines work to local advantage and do not decrease local primacy. One way to do this might be to convince local governments that uniform guidelines, backed by solid data, will first lessen the likelihood of lawsuits, and second will not place them at a competitive economic disadvantage with respect to other jurisdictions.

Thus we need a three-way data base--the same old three I've been preaching about for years: legal, economic, physical.

We need to know who has legal jurisdiction over what waters and for what purposes. And, believe it or not--after 6 years we still have to convince lawmakers that not every permit denial constitutes a legal "taking."

We need economic data on the value of the inland sea. Oh, how we need that! Did you ever ask the State Department of Commerce and Economic Development for data--any data--on tourism attracted by water-related recreation? I did once, and a very pleasant fellow told me they didn't have such information because they never had done a study. Watch the charter boats put out from Westport. Count the out-of-state license plates in the Anacortes ferry line. Then tell yourself the state knows those foreigners are wandering around up here spending their money, but it doesn't know what attracts them.

Port districts which berth a sizeable percentage of the commercial fishing fleet can probably tell you to the penny what they make on bulk alumina or a shipload of Toyotas, but they don't want to talk about fish landings. Partly because it isn't a big ticket item, partly I think because they fear acknowledgement of an economic benefit would lead inexorably to the admission that protection of downstream migration must be a criterion in design of port facilities.

What is the value of eel grass in Padilla Bay? Of an unbulkheaded beach where surf smelt spawn on Hood Canal? Of a sand spit left alone, a salt marsh unfilled, wetlands undrained? A lot of you are probably groaning right now because you see me sneaking up on the "how do you quantify the unquantifiable" question. This is also known as the how-much-would-you-pay-to-see-a-bald-eagle question. $10? $20? $30? More? Or its variation--how many miles would you travel to see a bald eagle? 10 miles? 20 miles? Etc. Etc.

One day last January I made a business trip to Lopez Island. As the Klickitat passed little Willow Island which always seems close enough to touch, there were 2 mature bald eagles perched in wind-gnarled fir on the island. Well, I didn't pay for the gas on that trip but I can tell you those 2 bald eagles cost me $10.20 round-trip ferry fare for car, driver and two passengers. And I can tell you we traveled 255 miles that day. I can tell you that only because I looked it up while writing this speech. What I can never tell you is the picture forever in my mind of the way those eagles looked in that tree on Willow, filed in my mind and ready to look at and think about any time I choose, any place I choose--for the rest of my life. What I can't tell you either is how that picture is stored in the minds of the others who saw the birds because each of us sees the world in his own frame of reference.

I think there are--and there always should be--unquantifiables in dollar terms. And that those unquantifiables are in truth often the richest aspect of life. So, as an offshoot of my economic data base I fling out the challenge to scientist and layman alike not to put a dollar value on the wonder of life, but to recognize that without this element of wonder our lives are truly poverty-stricken.

The third factor--and probably the one in which citizens' committees felt the greatest deficiency--was the physical data base. We knew some of the knowledge was out there in print, but had neither time nor know-how to track it down. And, as we soon discovered even the scientific community conceded that Puget Sound shorelines were sadly under-studied. In some areas of the inland sea, that is presently being remedied by state-funded baseline studies. How grotesque it seems that these study areas are biologically and economically among the most valued shorelines of the state, and that the studies are starting there to give us a base by which to measure future oil spill damage. Because in our fragmented management system we also picked these same locations for major oil transfer sites. And furthermore, our legislature is at this moment seriously considering making Cherry Point not only the common use terminal for all Puget Sound refineries, but also the transshipment point for the Midwest and the site of a petrochemical complex. How will our descendents evaluate this hodge-podge management of the inland sea?

But, back to the physical data base. I'm sure there are many approaches to evaluating intertidal and subtidal areas as well as the water column itself. One gross method which would be helpful for openers is a manual describing the obvious physical characteristics of shorelines and then explaining the life forms typically found in that habitat and their uses, values and place in the marine ecosystem. Both quantified and unquantified values. Also helpful would be the relative quantity of such shoreline found in the inland sea. Ranging from the common steep gravel beach to the uncommon undeveloped sandspit or stream delta. Such a manual might further discuss development on various types of shoreline, the expectable impacts, the possible means of mitigating damage. In some instances even broad benefit/cost ratios might be included. Comparing the benefit/cost ratio of a marina in a delta situation, for instance, with one on an ecologically less critical area, but on which the pile driving costs would be higher.

Another approach--and one which certainly should already be operative--is a site specific data bank compiled from the many environmental impact statements done for shoreline projects. These do vary tremendously in quality, but just as doctors review the work of fellow surgeons, perhaps the scientific community could establish a committee to review and verify to its own satisfaction the accuracy of EIS data.

Another major aid will be the Department of Ecology's proposed shoreline atlas.

But we must not think narrowly of only one or two such mechanisms. The danger is not, I assure you, in an overabundance of information or in possible overlap. The danger is that irrevocable decisions have been made and are being made every day without the fundamental knowledge you possess or probably possess. Baseline studies, data compilation and communication are essential if management of the inland sea is to succeed--and the greatest of these is communication.

Well, I've talked a long time and I guess I've covered about everything from the history of shoreline management and the political frustration of drafting master programs to the desperate need for more--and more accurate--information. Anyone asked to reduce this talk to organized outline form would probably take one look, sit down and have a good cry.

But that's o.k. We environmentalists cry a lot, too. Because we dream big dreams and hope big hopes and we work ourselves blue to make it all happen. We can stand the heat of the political kitchen. We've been in there a long time now speaking for the resources of the inland sea. But we need your help, your knowledge, now more than ever before. In the words of a somewhat better known and more eloquent speechmaker: "Give us the tools and we will do the job."

Thank you.

Do coastal regulations
do the job intended?

AGENCY, INDUSTRY, AND ACADEMIC VIEWPOINTS

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THE IMPACT OF PUBLIC LAW 92-500 ON PUGET SOUND

Donald P. Dubois
Environmental Protection Agency

Puget Sound is a priceless natural resource that provides recreation and commercial opportunities dependent on clean water. This priceless resource like others--can stand only so much punishment. PL 92-500 (The Federal Water Pollution Control Act Amendments of 1972) has as its prime objective the restoration and maintenance of the chemical, physical, and biological integrity of the Nation's waters. In other words, the Act was in part designed to prevent the punishment of waters--with generally good quality--such as Puget Sound.

It is an understatement to say the Act expanded the federal role in water pollution control. It raised the level of federal funding for construction of municipal sewage facilities. It elevated water quality planning and management to a new level of significance. It--rightly so--emphasized public participation. And it created a regulatory mechanism requiring uniform technology-based effluent limitations and a national permit system for municipal and industrial wastewater dischargers. The Act is very complicated and it is highly ambitious. But, it is working-- working to save Puget Sound and other bodies of water.

Nationally, EPA and the states have issued regulatory permits for over 20,000 industrial plants. Nearly 85% of these plants have complied with the waste abatement schedules built into those permits. Permit conditions are being monitored and enforced. For example--as reported in the news media we have recently taken enforcement action to insure all pulp and paper mills discharging into Puget Sound comply with the treatment requirements expressed in PL 92-500.

EPA, states and local governments have expanded levels of construction for sewage facilities. EPA's grant obligation last year was about $4.5 billion. This is 20 times the level of funding provided for in 1970. Industrial expenditures for water pollution control have also risen markedly. Construction of municipal and industrial wastewater facilities has created a new significant industry within our economy; many new jobs have been created.

Congress debated PL 92-500 for a long time before it was finally passed. A major reason for the lengthy debate was the issue of water quality based requirements versus uniform technological requirements. The Congress clearly came down on the side of uniform technologically based requirements for the entire nation. Specifically, they wrote into the Act the secondary treatment for cities and best practicable control technology for industries is to be installed by July 1977. By July 1983 treatment required is best practicable waste treatment for cities and best available technology for industry.

The legislative history of the Act shows that Congress felt that the Clean Water Act of 1965 failed to bring about desirable water quality and the basis of that Act was water quality standards. Setting ambient water quality standards and establishing individual waste treatment requirements to use up the full assimilative capacity of the environment was the traditional approach in water pollution control programs. Yet, much of the nation's waters became polluted. Congress decided the nation's waters are an economic asset that must not be polluted up to their capacity. Seattle residents had the unfortunate experience of having their Lake Washington bathing beaches closed by pollution. As we all know, they have fortunately been reopened because a massive effort was made to restore water quality.

There is more than enough evidence to show that the old water quality based policy will not work everywhere in a growing, changing country. So often, under that policy, the assimilative capacity of the receiving waters is first used up, then overwhelmed. And that means pollution. When that point is reached, the road back to clean water is long and costly. As a representative of a regulatory agency charged by Congress to protect the quality of our environment, I don't think we can afford to take the risk that we are smarter than we were in the past and, therefore, history won't repeat itself. But, in any case, the Law has abandoned the assimilative capacity concept.

Formulating waste treatment requirements here locally must consider the entire Sound, its dynamic nature and future development, and the effect of that development on water quality. Generally speaking, secondary or best practicable waste treatment is our best hope to provide a margin for further social and economic development and at the same time preserve the quality of Puget Sound. The state of Washington recognized this when they adopted an anti-degradation approach that calls for maintaining, wherever possible, existing water quality in high quality areas.

While high quality waters offer a margin of safety before significant water use losses occur, parts of Puget Sound are on the edge of that margin of safety. Water quality studies by EPA and the Washington Department of Ecology show degradation in certain relatively shallow bays such as Bellingham Bay and Port Gardiner Bay. And, it should be kept in mind there are numerous waste discharges to Puget Sound.

Many large cities such as Seattle, Tacoma, and Bellingham only provide primary treatment. There are a large number of industrial wastewater treatment plants also discharging into the Sound and adjacent waters. These primarily belong to the wood, metal, and petroleum industries.

The national goals for water quality are placed in jeopardy if toxics, oil and grease, nutrients, bacterial and virus organisms, and certain other substances aren't controlled to a reasonable level in waste discharges.

Therefore, treatment systems must be designed to remove or significantly reduce those substances which are or could be damaging to the marine environment. Toxic materials need to be greatly limited. Due to the potential direct and indirect influence of solids, treatment systems should provide a high degree of removal of these substances. Metals and pesticides absorb to solids in wastewater, thus settleable and suspended solids may incorporate a significant fraction of a waste's overall toxicity.

The need for the levels of waste treatment required by the Act becomes more pressing as our population grows and industry expands. In part, this is because it will be some time before technically and economically feasible means are available to provide adequate control of all forms of pollution, particularly those from non-point sources. Under Section 208 of the Act, however, we hope to correct some non-point sources of pollution. But, simple logic calls for the widest possible application of known and practicable water pollution control technology. There will be more than enough to do in water pollution control after that has been achieved.

From the earliest version of the legislation that resulted in PL 92-500, Congress recognized that achieving desired water quality may require more than base level treatment from point source discharges. For example, "non-point sources" of pollution are thought to contribute 92 percent of the suspended solids that enter the nation's waterways each year, and 98 percent of the fecal coliform. When these statistics are considered, along with the fact that a moderate-sized city washes from its streets and parking lots between a hundred and two hundred thousand pounds of lead and between six and thirty thousand pounds of mercury each year, we can begin to appreciate the importance of the work that lies ahead.

Our achievements up to now in water pollution control have come relatively easily. Now as we further restrict the pollution contributed by industry and invest more millions of our tax dollars in municipal and regional sewage treatment facilities, we find we must also address the growing proportion of pollution entering our waters from urban runoff and from carelessly managed farms and forests.

To help deal with these problems in the Puget Sound area, EPA has awarded planning and management grants under Section 208 to Seattle METRO, the Snohomish County Metropolitan Municipal Corporation, and the Washington Department of Ecology. The water quality management programs being developed by these agencies will deal with pollution from urban runoff, agricultural and forestry activities, and dredged spoil disposal.

We are quite excited about this program provided for under Section 208 of Pl 92-500, because it gives a challenging opportunity to states and local government to devise innovative water quality management programs. The federal government generally will simply be in a supportive role; providing financial and technical assistance. The process has built into it a heavy emphasis on involving the public in a major way. Plans are to be developed by November, 1978. And, if they are practical and implementable, local government can get federal and state bureaucracies out of their hair--at least with regard to certain water quality management issues.

With the catalyst provided by Section 208, EPA is committed to a full-scale effort to dovetail water quality planning with other environmental control activities and regional planning by elected officials and the public in general. Other legislation, such as the Coastal Zone Management Act and the State of Washington's Shoreline Management Act, coordinated with PL 92-500 should also stimulate wise planning to protect Puget Sound waters.

Another element of PL 92-500 which will impact Puget Sound is the industrial waste pretreatment provisions. Very recently EPA proposed four pretreatment options for review by the public. When final regulations are adopted and implemented we expect a significant reduction in the quantity of toxic substances reaching the waters through municipal sewage facilities. This activity will further be complemented by the new Toxic Substances Control Act. The effects of toxic substances are not adequately understood. Pathways, movement and action of toxic pollutants from point as well as non-point sources are not properly defined. There is, however, enough environmental information to support greatly limiting the discharge of all recognized toxic substances at the earliest possible date.

For the future, we expect Congress during the present session will deal with PL 92-500 in a positive way; i.e. the construction grant program will be continued at a high level of funding and Section 208 (water quality planning and management) will receive further support. Congress will also probably deal with the 1977 deadline for installing secondary treatment for all municipal wastewater. As much as 50% of the nation's cities can't meet the deadline--in part due to inadequate federal funding in the past. The Administration is supporting a case-by-case review with the potential for delaying the deadline until 1982-83.

In summary, this year Congress will be looking at the success or failure of Pl 92-500. I think they will find this 1972 Act has achieved its major objective--to get this country moving to control water pollution. The nation is making progress towards the goals of clean water which Congress established in the public interest.

Locally the goals of the Act are already met in many places and there may be examples of discharges to the Sound where an objective observer would be hard pressed to demonstrate overt harm. It is for that water quality reason that EPA and the Washington Department of Ecology have given a low priority for construction grants to certain cities discharging to the Sound. Instead we have jointly funded waste interception and combined sewer overflow projects. However, the water quality data and our knowledge of all the effects of the cumulative discharges to Puget Sound are not complete. I don't think the citizens of the Puget Sound area can have confidence in the future quality of the Sound if higher levels of waste treatment aren't installed. In addition to existing problems in localized areas, the possibility of subtle, long-term pollution effects raises doubts about the wisdom of sticking with the existing levels of waste treatment.

Secondary treatment or its equivalent is feasible--financially and technically. That requirement in PL 92-500 is intended to keep history from repeating itself for those waters that are still of high quality. At the same time, the requirements allow plenty of room for further urban and industrial development. We recognize, at this time, the environmental protection needs in Puget Sound are largely preventive needs.

Finally, EPA and DOE have implemented programs to control water pollution, not only from municipal and industrial point sources; but also from non-point sources and intermittent discharges such as logging, road building, dredging, and oil spills. The authority and driving force for many of these activities is PL 92-500. The law is complex and has many requirements, and, if it is carried out in a timely manner I think we can feel confident that the water quality in Puget Sound can be maintained or improved. This will guarantee the many recreational, commercial and aesthetic benefits that make living here so enjoyable.

THE REGULATORY SYNDROME

Marvin L. Vialle
Washington Department of Ecology

The topic which I am supposed to address today deals with Puget Sound regulations. "Do they do the job?" and "Are they unduly restrictive in terms of attempting to protect the resources of Puget Sound?"

First, I would like to say just a few words about the significance of Puget Sound. I don't imagine there is anyone in this room who does not recognize the significance and value of this resource; however, a reminder may be in order. Puget Sound is one of the largest inland bodies of salt water in the world, and it is abundant in many specific resources which are necessary and productive for the environment and for man. Fisheries resources in Puget Sound, on a commercial and recreation basis, are valued at approximately $59 million per year. The recreational resource, impossible to measure, but just in terms of the money spent to enjoy this resource, is approximately $134 million per year. The aesthetics, which are again impossible to measure, but to give some rough, conservative idea, the values of rural property bordering Puget Sound range from $150 per running foot to $205 per running foot. This represents a $1.5 billion value of non-urban Puget Sound frontage. These are just three of a myriad of values that are contained in what we know as Puget Sound.

The topic that I would like to address is: The Regulatory Syndrome. It is to deal with those regulations which have been adopted in order to protect these valuable resources. Prior to looking at whether or not these regulations are doing their job and whether they are unduly restrictive, I think we have to go back and look at why regulations were developed and how they were developed over time.

Regulations of one sort or another, either in law, formally adopted, or just societal understandings between two or more people have been in existence, basically, since there were people on this earth. It is said that when God created Eve, Adam's rights were cut in half because now he could not infringe upon her rights. Taking that one step further, every time the population of the world has doubled, mankind's rights have been cut in half.

Regulations are, by their nature, designed to protect the right of one individual from transgression by another individual. Regulations are also to protect those "things" with no voice or advocate in decision. First, though, it has to be agreed that the object of the regulation is worth protecting; in other words, that it has value.

Regulations have been developed over a period of time regarding traffic patterns on Puget Sound and throughout the other bodies of water--rules of the road if you will. These grew out of a recognition that the people and property plying the waters are of worth. There are certain recognized signals for passing. Sail boats not under power have the right of way over power boats, so forth and so on, as I'm sure most of you know. While most of these are not codified in terms of law or regulation, they are still "regulation" because they are recognized by society as rules which should be adhered to in order to protect that value which they are trying to preserve; i.e., life and reduction of injuries.

Perhaps in some people's eyes, the other end of the spectrum, is shoreline management--which is designed to protect the values that the people associate with having natural, unspoiled shorelines in portions of Puget Sound and assuring that reasonable uses are made of those shorelines where development does occur. Shoreline management attempts to strike a balance between the individual's freedom to develop and the public's right to be assured that the development will not infringe upon society's desires and needs.

Other regulations that affect Puget Sound relate to shellfish harvesting, relate to fishing, relate to vessel traffic care, relate to ferries, relate to Indian fishing rights, relate to aquaculture, and so forth and so on. How were these regulations developed? Basically, they were developed in a piecemeal fashion over a period of time. No one sat down and said, "This is Puget Sound. We need a set of regulations to protect it." What happened instead was that a value was recognized, and the legislature--the bureaucrats--the public--whoever, developed a scheme to protect that value. There is nothing intrinsically wrong with approaching a problem this way. In fact, it is probably impossible to do it any other way. It is obvious that values and potential threats are not going to be recognized all in one fell swoop. It is not going to be the hand of God coming down to say, "These are all the values there. Let's develop a comprehensive regulation that will protect them." Just one example of values that cannot be recognized, either in planning or regulations, at a given point in time, is historic value. Development of Fort Warden in Puget Sound was designed to protect potential destruction by invasion. The area is now serving a recreational and historic purpose. It would have been virtually impossible to recognize these future values of this site at the time it was developed for military purposes.

There has been a great deal of controversy surrounding the Trident Submarine Base at Bangor. Who is to say that in future years this will not serve as a historical site showing the primitive military approach and weaponry once designed to protect our nation? The fact that development of regulations is piecemeal creates certain problems.

One problem is that new regulations are frequently adopted without review of regulations already on the books. This creates a potential for duplication, overlap, and conflict between one regulation and another. Also, there is the problem that a value that was recognized 20 years ago as being worthy of protection may, given society's changing needs and additional scientific information 1) not either need protection or be worthy of protection, or 2) may not be being protected in the proper manner because a regulation may not have been designed utilizing the best available information. It's a parallel situation with what is the best practical technology. Many of our environmental programs are based upon using best techology; however, what is best technology today is not necessarily going to be what is best technology next year. This is, of course, the reason for utilizing that approach; however, this has not been utilized for that long a time. Regulations such as those regarding land use, promulgated 20 years ago, which were designed to promote heavy growth in an area, might be actually counterproductive if now the desires are to develop a sustained moderate, or slow, or no growth policy.

Another aspect which must be taken into account is the fact that regulations are developed by those governments that are best able to address the problem at the time the regulations are developed. Essentially, you have a multi-jurisdictional system involving Puget Sound. You have the federal government with heavy involvement in Puget Sound. Look, for instance, at the Coast Guard role in Puget Sound. You have the state of Washington, which is a major factor in this. Within the state of Washington, you have a variety of agencies. You have, for instance, the Department of Ecology, the agency which I represent. You have the Department of Commerce and Economic Development whose mission is essentially to assist in the development of areas, including Puget Sound, for economic and employment reasons. You have the Department of Natural Resource; you have just heard Commissioner Cole, who has again a different mission. You have, perhaps coming up more in the future, the State Energy Office, and you have the Department of Fisheries, again a major contributor to what controls are placed in the Puget Sound area. I'm sure there are a number of others that could be listed. Each of these looks at the waters and shorelines of Puget Sound as it relates to its function and its legislative mandates. Beyond that, you have local governments who have a longstanding and very significant role within Puget Sound. Within the local government, of course, you have a number of cities and counties, port districts, and other entities, all of which have some jurisdiction in the area.

So, by the time you take all the federal agencies, all the state agencies, and all of the local governments and then develop regulations to protect certain, but probably different values over a long period of time, you essentially have a conglomerate of regulations. I guess the only thing that is really surprising is the fact that they work as well as they seem to or, indeed, that they work at all. I don't think this is necessarily the result of the regulations being developed that well; I think it's a result of the application of regulations basically being made by reasonable people.

Again, here, I would like to emphasize that I don't think that anyone is to blame for this situation developing. It has developed in every part of the country and every part of the world, I'm sure, and has developed because of the regulatory syndrome: Time, separation of jurisdictions, and the protection of differing values.

The next aspect of the regulatory syndrome relates to what, in theory, is the answer to the problems that I have raised, and it's called planning. Planning, in theory, is designed to look at the interrelationships of the various factors and to develop, out of those interrelationships, a comprehensive scheme to recommend protection and actions that will best serve the various interests. Unfortunately, planning, as a tool in this system, also falls into the regulatory syndrome trap; that is, plans in Puget Sound and, again, elsewhere throughout society, tend to be limited in scope, tend to be piecemeal, and they tend to be done over a period of time without adequate consideration given to other values and other aspects.

For instance, there is undoubtedly, somewhere, a comprehensive plan for boat launching ramps on Puget Sound. The probability is that there may be two or three of them by two or three different agencies. There are also, undoubtedly, plans for fishing patterns in Puget Sound. There may be some that are done by agencies. There may be some that are done by legislators, and there may even be some that are done by judges. You can go down the list, in terms of all aspects of planning, and I think you will find the same thing applies.

Take land use planning--there are land use plans for areas that border on Puget Sound. There probably is some semblance of a land use plan for each city and county which is bordered by Puget Sound. They are necessarily well integrated and well coordinated, they may not even recognize the same set of values. Some of this is inevitable. But over a period of time, with differing community values, with different jurisdictions developing them, we have fallen into this syndrome of piecemealing.

But I am not (and I can say this, having a background in planning) calling for a comprehensive plan of Puget Sound to be the solution to the problems, because I don't think it will solve the problems.

Now that I have outlined the process I'd like to more specifically address the questions of whether regulations are effective and whether or not they create undue burdens.

In my opinion, they are generally effective in protecting the values that have been identified and agreed upon. However, there are increasing conflicts between values that must be resolved. The most prominent of these is the conflict or potential conflict between assuring environmental quality and the need for energy sources, i.e., oil transport. The key questions here are:

1. What degree of assurance of environmental quality is acceptable--notice I did not say what degree of environmental quality. There is constantly a risk to quality--the question is to what degree can and/or should this be maintained.
2. What is the need and what are the practical alternatives available to satisfy those needs.

These appear to me to be the key issues being addressed by both the opponents and the proponents of increased oil transport on Puget Sound.

Regarding the question whether or not the current regulations are unduly restrictive? The answer, I guess, is an unequivocal, yes and no.

For the most part regulations are maintaining current societal values, and are being administered in a fair, even-handed way. If an individual or a company desires something that will result in a modification of the Puget Sound resource there are mechanisms which can be used for a determination of whether the individual rights outweigh any public rights and vice versa. The bureaucratic and judicial system serve as necessary vehicles to make those determinations and opportunity is provided for full consideration by all concerned parties.

On the minus side, as alluded to earlier, the regulatory syndrome has created a system whereby there are a diversity of agencies, governmental levels differing time frames for authorizations.

Without creating chaos in the structure there are steps that can be taken to make the regulatory system more workable.

One approach would be for review of regulations in a zero base concept. This would involve reviewing the values that today's society places on Puget Sound and looking at them as a totality rather than segments. This could then be used as a starting point for getting the federal, state, and local govenments to develop a regulatory scheme that will preserve and balance those values in a way best suited to serve the public's need. This approach may be an impossible dream, but perhaps worthy of concentrated attempt.

A second partial solution is to encourage and sponsor more regional efforts to develop management programs. For instance DOE is sponsoring and participating in a Grays Harbor study to develop an agreed upon solution to dredge spoil disposal. The effort includes 5 federal agencies, 4 state agencies, and 8 local agencies. Hopefully, and I am very optimistic, the study will produce a coordinated, agreed upon solution to this problem, and prevent secondary problems in regulation implementation.

The third suggestion is to work toward combining permit systems, particularly those that serve similar purposes. As an example, and it's only one of several, Section 10 permits, administered by the Corps of Engineers, are often required on the same projects that require Shoreline Management Permits. While I could think of several reasons why these are not administered as one, rather than two permits, I don't know how valid the reasons are, and strongly feel that an attempt should be made to integrate the permits.

In summary, overall the system works well, but there are areas in need of improvement. The solution is, I think, in terms of looking at what we have, looking at why we have it, and making whatever necessary changes there are to make it workable, to streamline it so that minimal delays and minimal red tape stand in the way of what is good development or good protection as opposed to--because of the piecemeal problem--slowing down those good ones, as well as slowing down the ones that should be slowed down or stopped. It is not in anyone's interest to delay a good or a bad project. It is in everyone's interest to allow a good project to go forward; and to stop, in the shortest possible time, a bad project.

BAYS AND ESTUARIES
The Ultimate Shoreline Management Challenge
for Local Government

Dennis L. Derickson
Snohomish County Planning Department

INTRODUCTION

It has always been a bit ironic to me that the effective date of the Washington State Shoreline Management Act and the beginning of my career as a professional urban planner occurred on precisely the same date, June 1, 1971. I suppose it should have come as no surprise to me then that my first work assignment was to begin the challenging task of translating this landmark legislation into an effective program for managing the extensive shoreline areas of Snohomish County. Little did I realize then just how demanding this job was going to be. After nearly 6 years, 146 shoreline substantial development permits, 1 shoreline inventory, 1 shoreline management master program and many Excedrin headaches later, I have formed a few opinions about this state's shoreline management program that I would like to share with you.

THE PROBLEM

My principal concern relates to the tremendous challenge facing the cities and counties responsible for managing the use and development of the Puget Sound Basin's extensive system of bays and estuaries. Although some of you may disagree, it is my belief that the problems confronting local governments, as they attempt to oversee the best long-term use and conservation of these particular shoreline areas, are becoming much more severe than those involved in managing any other type of shoreline resource. Although it is always dangerous to generalize, I feel that we have already succeeded in fulfilling the main objectives of the Shoreline Management Act in its application to most of our state's fresh water and non-estuarine saltwater shoreline areas. With adequate state assistance, local governments should be able to continue successfully implementing their shoreline master programs in these areas. However, it is my contention that even with the additional regulatory and financial support provided by the federal Coastal Zone Management Act, cities and counties in the Puget Sound Basin will not be able to insure that their bays and estuaries will be used and protected in accordance with the provisions of their Shoreline Management Master Programs unless additional steps are taken to strengthen their management capability. I might also add that I feel the cities and counties managing the bays and estuaries located on our Pacific Ocean coastline are facing the same challenge.

The primary emphasis of my paper will be to describe the principal aspects of this growing shoreline management problem facing local government. Where possible I will refer to the recent shoreline management experiences of Snohomish County to aid in this problem definition effort. I will also attempt to suggest some measures that would be helpful to local governments in improving their capability to effectively provide sound long-term management of their bay and estuary resources.

It is quite evident that a substantial number of important factors are contributing to the continuing and often increasing difficulties being experienced by cities and counties implementing shoreline and coastal zone management planning programs for the Puget Sound Basin's bays and estuaries. The factors I will discuss first relate directly to the intrinsic characteristics of these coastal zone resource systems and concern the major planning problems they create for local governments attempting to make wise long-term decisions affecting their future use. The other factors subsequently presented can be grouped around the specific problems involved in administering the present Shoreline Management Substantial Development Permit System in our bay and estuarine areas.

PLANNING ISSUES--INTRINSIC CHARACTERISTICS OF THE RESOURCE

The great multi-faceted value and inherent attractiveness of our bay and estuary resources is a dominating planning factor which in turn has placed great pressure on local government shoreline management planning and permit administration efforts throughout the Puget Sound Basin. Not only is the competition between potential users of these resources usually much more intense than in other shoreline areas, but the number of users competing for the use of any particular portion of these areas is often much greater. For example, even the pristine and semi-isolated Port Susan Bay/Stillaguamish Estuary located in the relatively undeveloped northern portion of my county is experiencing this kind of pressure. At least five distinct private interest groups (including aquaculture firms, farming interests, sportsmen, local residents, and conservationists), four state resource agencies, an Indian tribe, and the City of Stanwood are vigorously vying for use, control or protection of some of the same intertidal areas of this estuary. A proposal by an aquacultural firm to harvest the bay's abundant supply of softshell clams with mechanical harvesting equipment precipitated the current struggle, but its outcome will have long-term implications for the future use of this estuary which will extend far beyond clam harvesting. The present clam harvesting problem has also been complicated by the fact that jurisdiction over its possible resolution is shared by Snohomish and Island Counties, the Departments of Fisheries, Game, Natural Resources, Ecology, and the U.S. Army Corps of Engineers. In addition, several farmers wish to create additional upland farm land by diking some of the bay's wetlands, and the City of Stanwood would like the Corps of Engineers to undertake a massive dredging project involving rehabilitation of the old main river channel in order to improve navigation and water quality. This issue has finally become so embroiled in controversy that several state representatives have proposed new state legislation which would establish a two-year moratorium on mechanical clam harvesting until extensive studies have been conducted to determine its long-term impact on the estuary.

The Port Susan Bay dredging, diking, clam harvesting controversy also dramatizes how the fragile nature and very high long-term value of the Puget Sound Basin's estuarine resources complicates local government's shoreline management task. Unlike many other resource allocation programs where decisions are often made within a relatively short time frame (10 to 20 years), the special nature of our estuarine resources requires that we look much further ahead when committing them to future use. The scarcity of these resources combined with their fragile character and rapidly increasing long-term value for food production, recreation, transportation, and many other uses, has created an extremely demanding resource allocation challenge for affected cities and counties. The complexity and fragility of our bay and estuary biological and geo-hydraulic systems cause most resource-modifying shoreline development commitments in these areas to be basically irreversible. Thus, future use options of potentially great long-term value are eliminated each time local government approves consumption or development of bay or estuarine resources. At the same time, however, the pressure on local government to approve these irreversible modifications is often enormous. Furthermore, it is obvious that no matter how desirable the preservation of future estuarine use options may be, their preservation cannot always be used as an argument to stymie currently needed shoreline development.

SHORELINE MANAGEMENT PERMIT ADMINISTRATION

The Shoreline Management Substantial Development Permit System administered by local government is the principal mechanism used to implement the planning objectives for Puget Sound Basin bays and estuaries contained in each city and county Shoreline Management Master Program. Without effective local administration of this permit system, the legislative mandate contained in the Shoreline Management Act and the policies and regulations of local master programs designed to carry out this mandate are of little value. Unfortunately, the efforts by local governments to implement the objectives of their master programs, as they pertain to our bays and estuaries have not been totally successful. Although, the completion and adoption of their shoreline management master programs during the past 2 years have aided most cities and counties considerably in carrying out the shoreline permit issuance responsibilities assigned to them under state law, nuerous problems remain unresolved. Most of these problems are more severe in cases where the substantial development permit request involves a bay or estuary. Some of the most notable problems include:

1. a lack of adequate information about the complex and diverse array of interrelated estuarine biological and geo-hydraulic systems;

2. a confusing pattern of overlapping, fragmented and competing local government jurisdictional boundaries;

3. a variety of serious conflicts among the various state statutes controlling the use and development of coastal zone resources, particularly as they apply to bays and estuaries;

4. a complicated, uncoordinated and overlapping system of state and federal development permits;

5. an inadequate ability by local government to enforce substantial development permit requirements and performance conditions.

My analysis of the impact of these problems on Snohomish County's Shoreline Management Program indicates that they have had a pronounced effect on the amount of time and effort required to process substantial development permits for projects located on our bays and estuaries. From June 1, 1971 when the Shoreline Management Act became effective through March 1, 1977, Snohomish County has processed 246 substantial development permits. Of this total 51 were for projects located on bay or estuarine shorelines. Although they constitute only slightly more than 1/3 of the total permit volume, my evaluation indicates that these permit requests have required a disproportionately high percentage of the time and effort of all participants in the county's permit review process. On the average, each bay or estuary related permit request required between 50 and 60% more planning staff, Planning Commission and Board of Commissioner time to process than other types of shoreline permits. The most complex and controversial bay or estuary related permit requests often require 5 to 10 times more effort to process than the other types of permit requests.

The percentage of substantial development permit requests appealed to the State Shoreline Hearings Board, which were linked to Snohomish County's bays and estuaries, is also an indicator of the difficulties being encountered by local governments. Eight permits processed by Snohomish County have been appealed to the State Shoreline Hearings Board and of this total, 6 were located on bay or estuarine shorelines. The amount of planning staff time involved in processing these appeals has also been very high.

Information Deficiencies

Although our coastal zone resource data base is continually expanding, substantial gaps remain. Many of these gaps relate to our bays and estuaries. In Snohomish County for example, we still do not have adequate information about the composition or magnitude of our estuarine salt marshes and wetlands, nor do we know exactly how much of this productive resource remains in the overall Puget Sound Basin. We are then vulnerable to the developer who brings in a "hired gun" consultant who proceeds to tell our elected decision-makers that as a marine biologist he can assure them that removing another 90 acres of salt marsh from the Snohomish Estuary's ecosystem in order to construct a marine industrial complex, "really won't make any difference." Hopefully, data gathering projects now underway, such as the development of a Coastal Zone Atlas by the Department of Ecology, will reduce the magnitude of this problem. However, in many instances the only efficient method of acquiring needed project evaluation data is to compile it after a specific substantial development permit request is received by the local agency. This in turn may place a major strain on that agency's staff and financial resources, unless the applicant can be required to furnish the needed information in order to comply with the State Environmental Policy Act or other development ordinances.

Local Government Jurisdiction Problems

Although the boundaries of substantial development permit issuing cities and counties do not overlap, they often do not make much sense. In addition, politically and financially powerful development oriented special purpose agencies such as diking, port, public utility, and sewer districts often overlap and intertwine to form a complicated jurisdictional maze. To make matters worse, cities often compete with each other and the county to gain jurisdiction over certain attractive bay and estuary areas.

An example of this competition for jurisdiction in my county involved a major land owner in the Snohomish River Estuary who easily convinced the City of Marysville to annex his 120 acre salt marsh island in order to enhance his chances for developing the property. This annexation request was approved by the Snohomish County Boundary Review Board despite the strong objections of the Snohomish County Planning Department that the annexation would constitute a clear violation of the Board's legislative charge to create efficient urban service areas, maintain logical physical boundaries, and reduce the competition among cities for unincorporated territory.

Improved shoreline planning and management coordination have been achieved through the development of master programs, but permit administration problems continue to occur on a regular basis. In my opinion the only real hope for additional jurisdiction coordination in bay and estuary shoreline areas would involve having the legislature impose a stronger mandate on boundary review boards and affected state agencies to require it.

State Statute Conflicts

During the 88 years since statehood, the Washington State Legislature has enacted a multitutde of laws affecting the use of our bays and estuaries. For example, several chapters of the Revised Code of Washington are devoted entirely to the subject of enabling legislation for port districts. Similar treatment is also given to a number of other related subjects. When so much legislation is devoted to the use of one particular resource, major conflicts inevitably occur. Some of these conflicts even involve the state constitution. These conflicts threaten the ability of local governments to carry out the policy mandates of the Shoreline Management Act embodied in their individual master programs. This threat is particularly serious with regard to bays and estuaries. One glaring example is found in RCW 53.25 which grants the port districts of this state the power to classify undeveloped tidelands within their jurisdiction as marginal land regardless of their actual characteristics or overall public value. The mere fact that a parcel of land is subject to being submerged by water is enough to qualify it for "marginal land" status along with any of several other loosely worded conditions. The simple passage of a resolution by the commission of a port district declaring this tideland to be marginal land is considered by RCW 53.25.210 to be prima facie evidence that such land is marginal as defined in RCW 53.25.030. No other criteria or evaluation process need be used. Such a designation by the port district then makes these so called marginal lands eligible for condemnation, reclamation and ultimate development as port facilities. Once such condemnation action is taken, a port district is in a strong position to pressure the local municipality for development approval and even major revision of the local shoreline management master program where necessary.

Another serious problem has been created for local governments attempting to implement their shoreline management programs by an outdated provision of the state constitution. In my Snohomish County example, the City of Edmonds found itself in a serious dilemma when it attempted to encourage multi-purpose public access oriented use of its shorelines. The project involved construction of a recreational fishing pier off the end of the Port of Edmonds marina breakwater by the State Department of Fisheries. Just when it appeared that all major obstacles to this much needed project were finally eliminated, the Department of Natural Resources (DNR) announced that it would not enter into an inter-agency land use agreement which would have permitted the Department of Fisheries to obtain a long-term lease for the use of the tidelands under the proposed pier. DNR stated that such a lease agreement would be illegal because the state constitution requires that all designated harbor areas be utilized strictly for port and navigational purposes. However, after considerable pressure was put on DNR by numerous state legislators, the department agreed to enter into the lease agreement with the Department of Fisheries by classifying the fishing pier as a "temporary use" although the lease would actually run for more than fifty years.

Although in this instance the story had a happy ending, I still believe that a thorough review of all state laws should be undertaken and that a concerted effort should be made to eliminate the major statutory conflicts which threaten to undermine our efforts to achieve good shoreline management, particularly in our bays and estuaries.

UNCOORDINATED STATE AND FEDERAL PERMIT PROCEDURES

The wide assortment of permits and approvals required by various state and federal agencies for projects located within this state's bays and estuaries has led to numerous problems for local governments as they administer their shoreline management programs. I am sure many of you have had your own first hand experience in trying to muddle through this permit maze, so I won't attempt to describe all facets of this problem. However, I would like to discuss one particular problem which too often makes an unnecessary contribution to local government's permit adminstration difficulties. This problem relates to the failure of some state and federal agencies to consistently notify applicants for their particular permits, that they should also check with the city or county having jurisdiction to determine whether or not a substantial development permit is required. I speak with considerable experience on this subject because too often, the staff of our department has encountered prospective shoreline developers who have made us the target of their anger, disappointment and frustration after being told that they would have to obtain another permit, when in fact the blame for their unnecessary permit delay rested with another public agency.

Better still, I believe we should work toward establishing a permit coordination system whereby all local, state and federal agencies would be required to specify that their shoreline related permits would only become valid after the applicant successfully obtained a substantial development permit or provides written confirmation that one is not required. Compliance with this requirement would not be that difficult for most public agencies and it would provide substantial benefits to both permit applicants and local government. Hopefully, some significant permit coordination reforms will be undertaken, which would begin to alleviate some of the major problems related to shoreline management permit administration. For example, greater use and further modification of the state's existing Environmental Coordination Procedures Act would lead to some notable improvements in the coordination of state permits for major project actions.

Full implementation of the "federal consistency" requirement outlined in the Coastal Zone Management Act's regulations would also insure that federal agency actions and permit approvals would not conflict with the processing of substantial development permits by local government. However, I am disturbed by recent reports that certain federal agencies are making a concerted effort to weaken these regulations. Finally, recent use of federal Section 306 Coastal Zone Management funding by the Department of Ecology to assist in providing permit coordination personnel in other state agencies and departments is already providing some improvement in the present state shoreline permit coordination efforts and should be continued.

ENFORCEMENT OF THE SUBSTANTIAL DEVELOPMENT PERMIT SYSTEM

A persistent problem for most local governments during the past 5½ years has centered on the difficulty of achieving effective enforcement of their Shoreline Management Substantial Development Permit Systems. As was the case with the other permit administration problems discussed previously, permit enforcement difficulties often seem to be the most severe in bays and estuary areas. The reasons for this are directly linked to the factors contributing to the other administration problems discussed previously.

My experience in Snohomish County has led me to believe that the most serious shoreline management enforcement problem is not related to apprehending fly-by-night developers who are conducting shoreline development activities without any local permits. Instead, the main problem for local government seems to be to consistently and effectively insure that developers (both public and private) carry out their shoreline projects and activities in full accordance with the provisions set forth in their properly obtained substantial development permits. Unfortunately, it seems that most local governments along with the Department of Ecology and State Shoreline Hearings Board are better at prescribing permit conditions than enforcing them. The chronic shortages of enforcement personnel and adequate legal assistance experienced by most local governments have been a prime contributor to this problem. Typical local government budgetary priorities dictate that permit processing activities must take priority over permit enforcement. Vigorous permit enforcement action at the local level can also be politically risky for local officials, which may explain the conspicuous lack of local enthusiasm for such efforts.

In Snohomish County no major effort has ever been undertaken to review all of the more than 120 substantial development permits which the county has issued during the past 5½ years. Such a review would be intended to determine whether all conditions specified on the permit for performance of development and operation have been met satisfactorily. I suspect that few other local governments have conducted such an enforcement review either. Instead, as in our county, they have probably struggled along, responding where possible to complaints regarding individual shoreline projects.

Hopefully, the provision of Section 306 Coastal Zone Management funds to local governments to aid in permit administration efforts will encourage more active permit enforcement programs. In fact, the City of Seattle is beginning efforts to undertake such a program already. My basic concern at this point is that unless active enforcement programs are undertaken by more local governments, particularly by those with bays and estuaries, future shoreline developers will be encouraged to disregard some of the important performance conditions attached to the shoreline permits authorizing their projects. I am fearful that a very undesirable situation could develop wherein many prospective applicants may readily agree to fulfill all performance conditions stipulated by local government in order to obtain substantial development permits for their projects, while actually having no intent to fully comply with these conditions once the project is undertaken. Although performance bonding and similar techniques can be used to supplement normal permit compliance procedures and reduce such potential abuses, they should not be considered as substitutes for active field enforcement programs.

It is also very important that in those situations where local government is unwilling or unable to take effective enforcement action against a violator, the Department of Ecology and the Attorney General's office must be prepared to promptly intervene and take appropriate action to insure compliance with the Shoreline Management Act. This has not happened in the past.

CONCLUSIONS

In conclusion, I urge you not to become complacent about this state's recent shoreline planning and management efforts. A good state and local government partnership has been established which has been responsible for development and implementation of the nation's best shoreline and coastal zone management program.

However, we face some unprecedented challenges which will focus on our Puget Sound Basin bays and estuaries, the most valuable and vulnerable coastal zone resources we have. Only a renewed effort by all local governments to effectively administer their individual Shoreline Management Master Programs, combined with the active and expanded support of the general public and all other public agencies at all levels of government can assure that the best possible long-term decisions regarding the conservation and development of these most unique and irreplaceable resources will occur.

THE RESPONSIBILITY OF A PUBLIC AGENCY IN ACCEPTING ENVIRONMENTAL RISKS IN THE USE OF PUGET SOUND

Richard S. Page*
Executive Director, METRO

This paper addresses the issue of environmental risk and what it means to a municipal discharger planning to meet the water quality goals of P.L. 92-500--the federal Water Pollution Control Act Amendments of 1972. As with any resource management decision, certain risks must be assumed in balancing the environmental, social and economic values of a community. A major issue in our present planning for the goals of that law is how much risk an agency should assume in making decisions that can affect its own region. More specifically, since METRO understands the various risks involved, should not METRO be allowed to make decisions affecting Puget Sound?

Making such decisions is nothing new for the Municipality of Metropolitan Seattle (METRO). METRO is a regional agency providing water pollution abatement and sewage treatment service to the communities in the Seattle metropolitan area. METRO is also responsible for public transportation. Serving a population area of about one million, METRO depends on Puget Sound for the economical and safe disposal of treated wastewater.

HISTORY

METRO was formed in 1958 to correct the major water pollution problems in the Seattle metropolitan area. Increased population and increased wastewater were the prime causes for a public health concern about Puget Sound and the eutrophication of Lake Washington.

Thirteen communities surrounding Lake Washington were discharging effluent into the lake after secondary treatment. In Seattle most of the sewage from a combined sewage system (rainwater and sewage) was discharged directly into salt water without any treatment at all.

Scientists at the University of Washington alerted the community to a pollution problem that would become more severe if something were not done. The environmental risks were extremely high. Citizens listened to scientific predictions and recommendations and then voted in 1958 to form METRO and tax themselves to finance a solution.

Present Address:
Urban Mass Transportation Administration
Washington, D.C.

Now 20 years and $150 million later all sewage effluent has been diverted from the lake and is treated prior to discharge to salt water. Treatment facilities include the 125-million-gallon-per-day West Point primary treatment plant, which is the largest municipal discharger to Puget Sound, and the 36-million-gallon-per-day Renton treatment plant, which discharges secondary treated effluent into the Duwamish River estuary, which flows into Puget Sound. Secondary treatment removes approximatley 85 percent of the oxygen-demanding materials from the effluent, while primary achieves approximately 30 percent removal. In addition to these new facilities, METRO operates three smaller plants that discharge primary treated effluent to Puget Sound: the Alki, Carkeek Park and Richmond Beach treatment plants.

These five facilities have been the basis of the Puget Sound area's significantly improved water quality over the past 20 years. METRO formed a laboratory in 1963 to monitor water quality and maintain data.

The goals and requirements of Public Law 92-500, however, have caused us to reexamine METRO's treatment processes. The law calls for elimination of pollutant discharges to navigable waters by 1985. The law also sets up two interim goals for 1983: protect fish, shellfish and wildlife, and make the waters "fishable-swimmable," or usable for recreation. "Best practicable" waste treatment (BPT) has yet to be clearly defined. The Environmental Protection Agency has defined BPT as secondary treatment plus additional treatment levels which will satisfy local water quality needs.

Thus another important decision, similar to that made in 1958, must be made this year. How can the goals of the law best be met? Are the best ways of fulfilling the goals of the law even legal?

While cleaning up Lake Washington METRO recognized that sound scientific advice is necessary to assist public agencies in arriving at the most environmentally sound, economically and socially desirable methods for achieving clean waters. METRO began planning for the BPT goal soon after P.L. 92-500 was enacted. Planning included attempts, with other water pollution abatement agencies across the country, to persuade Congress that the law should be amended to allow flexibility for agencies to meet both national and local goals.

The BPT effort was based on evidence from researchers. A 1973 scientific analysis of the central basin of Puget Sound, for example, strongly suggested that conventional secondary treatment--removing additional oxygen-demanding materials from wastewater discharges--might not be necessary to improve or maintain dissolved oxygen levels of Puget Sound. Further, Dr. Alyn Duxbury (1975), Professor of Oceanography at the University of Washington, concluded that nature, rather than man, apparently controls the overall water quality in Puget Sound.

Other research has suggested the potential serious water quality and public health concerns associated with combined sewer overflows into Lake Washington, the Ship Canal, and along the Seattle waterfront. Overflows of untreated wastewater result in uncontrolled discharge of toxicants, such as heavy metals. We certainly do not want raw sewage on freshwater swimming beaches during the summer, nor do we want the associated visual damage to the waters.

For these reasons METRO has worked to amend the law to allow ocean dischargers to bypass the secondary treatment requirement, whenever scientific evidence recommends this course, and to proceed directly to actual water quality problems and achieve the goals of the law through best practicable treatment technology. However, no legislative changes have taken place to allow agencies this flexibility. Secondary treatment, METRO believes, is not the only way to insure high water quality. A decision to bypass the 1977 secondary treatment requirement could allow money to be spent on more obvious water quality needs such as reduction of combined sewer overflows. This course would still achieve the goals of P.L 92-500 without the arbitrary commitment to secondary treatment which has no predictable benefits to Puget Sound.

Before passage of P.L. 92-500, METRO was already working in partnership with the Washington State Department of Ecology and its predecessor agencies in developing and implementing a comprehensive water quality management plan for the Seattle metropolitan area. We believe we have succeeded in tailoring a plan to meet the physical, social and economic requirements of this area for clean water. Lake Washington and Elliott Bay are cleaner than before and generally meet the "fishable-swimmable" goal of P.L. 92-500. Both water bodies are intensively used and enjoyed by the citizens of this community.

Since many of the requirements of P.L. 92-500 were foreseen by the state of Washington and METRO before the law was passed, a $4½ million planning program, supported in part by the Environmental Protection Agency and Department of Ecology, was already underway. The River Basin Coordinating Committee (RIBCO) provided a comprehensive approach to regional planning for land use, water resources, water quality, urban drainage, and solid waste management. The water quality element of the planning was consistent with section 303(e) of P.L. 92-500 which called for a continuing planning process for intrastate waters. Even facilities planning requirements of section 201 of P.L. 92-500 were foreseen, since previous laws had laid the groundwork.

METRO's areawide water quality planning (Section 208 of P.L. 92-500) is a continuation and a refinement of the planning achieved by our RIBCO studies. These efforts allow for the identification and establishment of priorities for the serious water quality problems in the Seattle metropolitan area.

The National Pollution Discharge Elimination System (NPDES) permit requirements of the law necessitated a more formal method of monitoring discharges from our treatment plants to Puget Sound. We were already working with the state, however, to insure that effluent discharges conformed to its policies. Another requirement of the law is that private industry pay user charges for municipal systems and share in costs for capital facilities. But METRO already had an agency policy encouraging industry to manage cost-effectively the type of wastewater entering the treatment system. For the most part, then, METRO has anticipated the requirements of P.L. 92-500, which will be useful in guiding METRO's water quality management decisions.

But, as mentioned earlier, the secondary treatment requirement under Section 301 has been difficult for METRO to justify for Puget Sound, which has characteristics of high salinity, low temperature and reliable flushing. This section of the law sets aside previous water quality planning pursuant to 303(e) and the present areawide planning. Consequently, for METRO this one section of the law has raised an issue that overshadows its many positive aspects. As it stands, the law prevents local agencies from tailoring treatment methods that meet local water needs and community goals. We believe at the time the law was passed, the social and economic implications of the secondary treatment requirement were not clearly understood by Congress, nor were the secondary environmental effects of planning specifically for water quality protection considered.

Therefore, METRO has been evaluating the effects of this decision that provides for clean water only through secondary treatment. We are studying other options directed by meeting national and local water quality goals, because we have an obligation under environmental and cost-effective guidelines. The options include solutions to the water quality problems created by combined sewer overflows.

National and state environmental policy acts require evaluation of all reasonable alternatives for achieving the goals of P.L. 92-500, including "no action," where a proposed action could have a significant impact on the quality of the human environment. We believe the memorandum of understanding among EPA, DOE, and METRO will assure a decision which meets the goals of NEPA, SEPA and P.L. 92-500. Thus, the environmental policy acts are insuring coordination among agencies, a thorough evaluation of alternatives and a method for public involvement in the planning process prior to decision-making by the agencies.

ARE THE WATER POLLUTION ABATEMENT LAWS NECESSARY?

Laws approved by our various legislative bodies represent the will of the general populace in setting specific requirements for managing natural resources, such as Puget Sound. However, we believe federal laws and regulations should allow flexibility. Local communities should be able to choose the best method of achieving overall national goals from a variety of alternatives, while remaining in concert with the goals of the community. In the long run it is the community that has to live with environmental, social, and economic consequences. The community is responsible for payment of potentially large yearly operation and maintenance costs. Even though federal money is available for 75 percent of the capital costs, the economic impact could be substantial. We believe that P.L. 92-500 as interpreted by EPA regulations and officials does not yet allow METRO to assume even minimal environmental risk in using Puget Sound for the disposal of primary treated effluent. For example, the law now prevents us from using the natural assimilative capacity of Puget Sound. For the past 15 years we have undertaken many studies and worked with scientists from other agencies and institutions to learn the relationship between treated wastewater and this assimilative capacity of the Sound.

The question we continually ask is this: Has the effluent adversely affected the fish, shellfish and wildlife resources that are dependent upon Puget Sound? In 1974, recognizing that the answer to that could have substantial social and economic consequences, we committed $1 million and initiated additional intensive studies of Puget Sound adjacent to our treatment plants to examine closely the environmental risks. When the studies began in 1975, water quality information for Puget Sound was insufficient for completing our decision-making process. Our studies were undertaken to complement previous efforts and other more comprehensive studies including Marine Ecosystem Analyses (MESA) studies by NOAA and the Puget Sound Baseline Study by DOE. We are committed to obtaining a better understanding of the possible environmental consequences of alternative actions we might take to meet the goals of the federal law.

Preliminary results of our studies show that the risks involved in continuing with the present method of discharge do not appear to be significant. In fact, no adverse impact to Puget Sound as a whole has been detected. A quote from the study report by Collias and Lincoln (1977) is appropriate: "From these data, both new and old, it is concluded that the sewage entering the main basin of Puget Sound from the sewers of METRO and other sewage systems has had no measurable effect upon either the nutrient concentrations or the dissolved oxygen content except in the near field at the outfall. The near field effect is very localized and has no impact upon the entire system."

In short, the basic intent of the secondary treatment requirement of the law is to reduce oxygen-demanding material in the effluent. But Puget Sound is an oxygen-rich water body in which our effluent discharges have caused no apparent dissolved oxygen depletion problems.

METRO has done other kinds of research related to secondary treatment. In addition to performing water quality studies, METRO has spent more than $1 million on a Pilot Plant program studying alternative methods of wastewater treatment. These studies show that secondary treatment can increase the removal of some toxicants as well as remove oxygen-demanding materials. Because toxicants, such as heavy metals, readily adhere to organic materials, more toxicants would be removed by the secondary treatment process. But after careful analysis, scientists studying heavy metals in Puget Sound are having a difficult time predicting any serious water quality problems associated with heavy metals that would degrade the fish, shellfish, and wildlife inhabiting Puget Sound. Shell (1977) has illustrated the relative amount of certain heavy metals entering Puget Sound (Table 1). Major sources are natural or from ship hulls, not effluent from wastewater treatment plants, and do not appear to be harmful.

As with any scientific study involving biological systems, it is very difficult to understand completely the interrelationships of all organisms within the Puget Sound ecosystem. It is equally hard to be definitive about the significance of environmental impacts. Consequently, it is impossible to argue that these studies support a 100 percent assurance of no risk to Puget Sound with the present method of wastewater treatment. Conversely, the studies cannot clearly show that secondary treatment, as required by the law, would have no benefit. We now understand that there is probably a minimal and possibly even a nondetectable reduction in the risk of environmental damage to Puget Sound involved in a commitment to secondary treatment. This speculation is based upon the simple fact that secondary treatment reduces the amount of foreign materials placed in the water.

Since Puget Sound is large and our understanding of the ecosystem is limited, we must continue to be certain that our judgment of minimal environmental risks is truly accurate. Puget Sound is not an infinite "sink" for our waste materials, and its assimilative capacity must be determined, continually monitored and not exceeded. New developments in technology could improve our methods of measuring components of the ecosystem and thus provide a better understanding. One way to continue to assess these risks would be to maintain a comprehensive program of monitoring Puget Sound

Table I

Total Copper, Lead and Zinc Inputs to Puget Sound
Metric Tons/Year

Puget Sound Source	Copper	Lead	Zinc
Rivers (Lake Washington-Ship Canal included)	787	2032	1624
Metro's West Point Plant	29	9	56
Other Municipal Treatment Plants	22	16	26
Atmospheric Input	45	273	82
Vessels Protective Measures and Fuel	360-590	9-12	140-240
Urban Runoff (Seattle)	15	350	50
Advective Transport (Admiralty Inlet)	65 (306*)	1640	874

*306 tons/year is based on a copper concentration of 0.8 ug/l which is considered more realistic than the value of 0.17 ug/l found in sampling during this study.

Source: William Schell, (1977)

water quality. Such a program could provide forecasts of environmental risks long before the significant environmental problems materialized and time for all users of Puget Sound to reevaluate previous policy commitments.

METRO's Puget Sound studies also examined possible environmental impacts in the near shore areas immediately adjacent to the treatment plants. At West Point, for example, the studies showed that during some times of the year diluted effluent is carried by onshore eddies during certain tides to nearby beaches before it is dispersed in Puget Sound. The preliminary results suggest possible effects on intertidal organisms and/or public health. However, the results from more direct studies of the organisms suggest that the local impact is not significant and therefore, as with Puget Sound as a whole, the environmental risk is minimal. In order to assure that the risks remain minimal, METRO is in the process of initiating research programs to determine the frequency and severity of this phenomenon.

CONFLICT WITH LOCAL COMMUNITY GOALS

A commitment to secondary treatment at the West Point treatment plant would result in the need to fill up to 12 acres of the tidelands adjacent to the plant, as well as to expand the plant substantially. West Point is situated next to Discovery Park, a large, relatively natural area within the City of Seattle; additional treatment facilities immediately adjacent to the park would not be in keeping with the goals of the city. Furthermore, the City of Seattle under the Washington State Shorelines Management Act of 1971 has designated the tidelands in question as "conservancy natural." Without a change in the city's policy, filling would not be allowed. In addition, the city has recognized the conflict and has indicated an intent to permit expansion if no feasible alternative exists.

Here then is the dilemma at hand: Will the commitment of financial resources by this community for both capital and annual operation costs be worth the apparent minimal reduction in environmental risk to Puget Sound? We must judge carefully the environmental risks of maintaining primary treatment, committing ourselves to secondary treatment, or choosing an alternative that solves the real water quality problems that have been identified with combined sewer overflows.

We urge all experts to assess the environmental, social, and economic impacts we can anticipate from each specified use of the Puget Sound resource. Our assessment must be presented to our decision-makers so they clearly understand the environmental risks assumed in making decisions for public health and welfare. The Metropolitan Council in concert with EPA and DOE will have to make decisions within the next 6 months. The initial comprehensive studies are over, and the information is in. Consulting engineers, members of the scientific community, and agency staffs are busy interpreting this information and developing recommendations. We invite all interested citizens to assist us in interpreting the studies and providing an assessment of environmental risks.

SUMMARY AND CONCLUSIONS

It is essential that legislative and regulatory agencies be constantly aware of new scientific information on Puget Sound, since they are responsible for developing laws and regulations to guide public agencies and private industry in making policy decisions for the wise use of this resource. Laws and regulations must be updated to reflect the latest scientific information and to recognize the financial, land-use and environmental tradeoffs involved. If scientists believe a reduction in that risk is unnecessary, and if policymakers decide the effort is socially, economically, and environmentally unfeasible, we must ask that the law and/or the EPA regulations be changed. Public Law 92-500, as it is currently interpreted, is an example of an inflexible law that only addresses waste treatment technology, does not permit local agencies and communities to address the full range of water quality needs and priorities, and does not provide for the full consideration of other environmental goals.

METRO remains committed to its original goal: clean waters in the Seattle metropolitan area. The soundest way to achieve that goal is by rigorous and open examination of environmental risks and tradeoffs, the ranking of water quality priorities and the eventual selection of alternatives which are the most cost-effective.

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PUBLIC LAW 92-500 OR KILLING FLIES WITH SLEDGEHAMMERS

Lawrence E. Birke, Jr.
Northwest Pulp and Paper Association

Pollution abatement in the United States has essentially been accomplished under two different philosophical approaches:

The *environmental quality* approach

The *technological* approach

The environmental quality approach is characterized by local regulatory agencies conducting measurements in the air or water to determine what needs to be done to improve or maintain the quality of the environment. Specific pollutants at specific sites are addressed and regulations or discharge permits are developed with reference to well defined goals. It was under this approach that major cleanup programs such as Lake Washington or the Willamette River in Oregon were accomplished.

The technological approach is not directed towards the solution of site-specific problems. This approach is characterized by an evaluation of existing or available technology by regulatory engineers or scientists. From this evaluation, facilities or performance criteria are developed which are then applied to all applicable dischargers without regard to specific location. While the technological approach is applied on a national level it clearly has enforcement advantages at the local level. With this approach it no longer becomes necessary for the regulatory agency to make comprehensive measurements in the receiving air or water to determine enforcement action. Simple inspection of the pollution abatement facilities and review of its discharge performance (measurements usually required of the discharger) are all that is needed to initiate action.

Pollution abatement in the United States, until the early 1970's, was almost entirely accomplished by means of the environmental quality approach. In the late 60's, however, a growing discontent with the success of pollution abatement efforts coupled with extreme public activism resulted in a major environmental movement. This movement, characterized by the massive marches on Washington, D.C. and boycotts and protests against industrial "polluters," put considerable pressure on Congress to take definite and often drastic action to improve the quality of the environment. While recognizing that many of the environmental laws passed in the late 60's and early 70's had not yet begun to take effect, the Congress nevertheless responded with new legislation. Most significant among this legislation were the 1971 Clean Air Act Amendments and the 1972 Water Pollution Control Act Amendments.

Probably the most revolutionary of any environmental law passed to that date, the Water Pollution Control Act Amendments of 1972 (PL 92-500), for the first time mandated that a uniform level of technology be required nationwide. The Environmental Protection Agency (EPA) was directed to develop applicable levels of technology for all major industrial and municipal dischargers in the country. Dates were established by which time this technology was to be in place: July 1, 1977 for "Best Practicable Technology" and July 1, 1983 for "Best Available Technology." Finally the Act specified that by 1985 the country would achieve '0' discharge of pollutants into all waters. Needless to say, the cost, implications and benefits of complying with the provisions of the Act were only vaguely, at best, understood in 1972.

As industrial and municipal dischargers approach the first major deadline of PL 92-500 (the 1977 requirement for Best Practicable Treatment) it is appropriate to review how well this new philosophical approach to water pollution abatement adopted by Congress has been translated into practice. At first glance the achievements are encouraging--significant improvements in cleaning up the environment have been made. A closer inspection of pollution abatement programs however uncovers a number of problems which over the past 5 years have caused industries, municipalities, and even the regulatory agencies to question the overall cost-benefit results of PL 92-500.

The fundamental problem with the implementation of the Water Pollution Act Amendments of 1972 is inherent in the definition of the technological approach which has been adopted. No differentiation has been allowed for local environmental conditions. For the implementation of water pollution abatement facilities the Act assumes that the waters of the U.S. are equal in their needs, conditions, and problems. Obviously this is not so. The waters of Lake Erie are not the same as the waters of Ketchikan, Alaska, nor are the waters of Puget Sound faced with the same problems as the Mississippi River. When uniform treatment is required on a nationwide basis inequities in costs and benefits results[1]--inequities not only in terms of dollars, but also in the consumption of valuable resources and energy.

The municipalities and industries on Puget Sound are particularly affected by the negative impacts of a nationwide uniform treatment approach. The technology of "secondary treatment" has been specified as "Best Practicable Treatment" for all cities and pulp and paper mills on the Sound. This process technology was "transferred" from fresh water locations where it often produces significant pollution abatement to marine dischargers where it addresses "pollutants" which usually cause no measurable effect on the receiving waters. Independent environmental studies by academic, consultant and even regulatory agency researchers have agreed that at a majority of Puget Sound locations little or no benefit will be derived by the implementation of costly "secondary treatment" facilities As the same time, however, millions of dollars will be diverted from production facilities, millions of kilowatts of electricity will be used, and thousands of tons of chemicals will be consumed in the construction and operation of the treatment plants. All these problems will result because the 1972 Act does not contain sufficient flexibility to address the conditions and requirements of local receiving waters.

The second major problem which has developed since the Act was passed in 1972 involves the interpretation made by the EPA and the courts on how the Act should be implemented. For example, recent federal court rulings in the Northwest have indicated the water quality data are not admissible evidence in judicial review of individual permit requirements. The irony of trying to comply with a "water pollution law" which does not allow the discussion of "water quality" has caused much concern by all dischargers and has resulted in an enormous wave of litigation.

To facilitate implementation and enforcement of various provisions of the Act, EPA has chosen to take a rigid, unflexible approach in their activities. For example, while the Agency was over 3 years late in promulgating discharge guidelines for the pulp and paper industry, they have been insistent that the industry meet its technological compliance date of July 1, 1977. In Puget Sound and the marine waters of the Northwest where the benefits of that technology is at best questionable, many companies have chosen to appeal their permit requirements through "due process" options of the Act. Nevertheless, EPA has taken the position that companies should "litigate on their own time" and in turn has pressed for court imposed fines for noncompliance. In criminal law this would be equivalent to having the accused serve a prison term even before he has received a court verdict of his guilt or innocence.

Many problems have also occurred between regulatory agencies in implementation of the Act. Provisions of PL 92-500 allow state regulatory agencies to apply for and be granted permit issuing and enforcing authority. This option has been exercised by the state of Washington. Several of the discharge permits issued by the Washington Department of Ecology (WDOE) have been vetoed by EPA. These actions have resulted in additional litigation wherein the state and the industry are in court as joint defendants testing the validity of these permits agains EPA. The state has contended that they do have sufficient authority under the Act for their action and that they have a better understanding of the needs of Washington receiving waters than EPA. They point out that Washington had an active and progressive environmental regulatory agency even before EPA's formation.

In Puget Sound millions of dollars have been spent and are continuing to be spent on pollution abatement facilities by the pulp and paper industry. The industry has reduced water pollutants discharged during the period 1965 to 1977 by over 85%. All this accomplishment has occurred while generally developing a spirit of cooperation with the WDOE and maintaining a viable employment base for over 30,000 Washington residents. In their questioning of the benefits of uniform "secondary treatment" technology for Puget Sound, the pulp and paper industry is joined by many other industries and municipalities. The issue is clearly then not one of resistance to water improvement requirements, but rather an insistence that the total environmental benefits be required to outweigh the negative impacts of facility development and operation.

When Congress passed PL 92-500 in 1972 many recognized that the approaches outlined in the Act were revolutionary and untried. Consequently, the Act also set forth a requirement that a National Commission on Water Quality be created to review the implementation of PL 92-500 and report back to Congress with needed "mid-course corrections." After more than 3 years work in all 50 states, expending more than 17 million dollars, the Commission, headed by Nelson Rockefeller, reported out a series of recommendations in late 1976. These recommendations go right to the heart of many of the problems of implementation of the Act. For example, the Commission recommended: 1) more flexibility needed to be put into the Act; 2) the 1983 deadline should be postponed until an assessment of the 1977 technology could be made; 3) 1977 technology requirements could and should be postponed on a case by case basis for municipalities and industries; 4) the states should be given more authority in implementation of the law. Numerous other recommendations were made ranging from municipal waste treatment funding to non-point water pollution problems. These recommendations and others will be reviewed by Congress in 1977 for possible enactment.

The Puget Sound region, its environment and economy, will be greatly affected by the modifications, or lack of action, to PL 92-500 during 1977. Limited energy, chemicals and dollars must be optimized in their use to combat water pollution. We no longer can afford the indiscriminant use of our resources regardless of the benefits to be derived. Further, the impact on the total environment and not just one sector must be assessed before we take action. If water pollution abatement facilities are going to be constructed, positive benefits to the receiving waters must outweigh the negative impacts of increased air pollution, solid waste, noise and energy consumption. The pulp and paper industry of Puget Sound will continue to make major contributions to improving the environment yet at the same time we will increasingly question and evaluate the total "costs" versus the benefits to be derived. Only in this way can we guarantee a better quality of life not only for ourselves, but for our posterity.

A PUBLIC AGENCY'S VIEW ON MARITIME TRANSPORTATION ON PUGET SOUND

Capt. Merle Adlum
Commissioner, Port of Seattle

This afternoon's topic: "Federal, State and local laws, regulations and guidelines: Are they required, and do they do the job that was intended to conserve and protect the marine environment without being unduly restrictive?" provides me with an opportunity to speak out with considerable confidence and knowledge.

Most of my life has been dedicated to the two most prominent values of the topic question, the maritime use of Puget Sound and navigational safety programs for vessels entering and departing Puget Sound waters. The subject of "maritime uses" interests me because of my 14 years as a Port of Seattle Commissioner, and the subject of "navigational safety" from my long experience as President of the Inland Boatman's Union, a licensed Puget Sound pilot and a master mariner with many years' experience captaining major vessels throughout our portion of the world.

I referred to "maritime use" and "navigational safety" as being the prominent values of the topic question because there is no way that the topic can be fully discussed, or analyzed, without a full understanding of the need that has been placed on Puget Sound by a worldwide increase in shipping demands and the practical safety programs that have been well-studied and implemented. These two values could easily lead to long discussion, but because of the necessary time limitations on today's presentations, I am going to keep my remarks brief in order to leave time for questions and answers.

In this presentation I am going to limit my remarks to two specific areas:

> The importance of Puget Sound to the explosive worldwide growth of maritime trade, including the highly controversial oil tanker consideration, and
>
> The natural and programmed safety features of maritime traffic on Puget Sound.

There are some who would argue that the increasing efficiencies in the maritime shipping industry are the basic factors for the rapid increase in world maritime trade. This, however, is really a "chicken or egg" circle of logic since it really doesn't make any difference, the point being that maritime commerce has made a phenomenal tonnage increase. Within the last decade the world has rapidly shifted toward a worldwide economy and the backbone of this economy is dependent upon maritime commerce. Worldwide increases in affluency; national economic specializations that are based upon a world economy (such as is the case with Japan); the expanding search for natural resources by all nations, have all contributed to the rapid growth in maritime transportation. We have witnessed a yearly increase of some 9.5% in world exports over the last decade, an overwhelming majority of which is in maritime trade, compared to a yearly growth of only 5.8% for the gross world product. The last half of the last decade, furthermore, saw worldwide exports speed up to a 11.1% yearly growth. Even for the U.S., our foreign trade is increasing at a faster rate than our gross national product. This demonstrates that we are becoming increasingly dependent upon a world economy which is based upon low-cost, energy efficient water transportation.

The importance to Puget Sound of this growth in maritime trade is that it has not been evenly distributed throughout the world. The Pacific Rim in particular has felt the greatest overall effect. The impact upon U.S. West Coast ports from the combined interaction of the rapidly expanding economies of Asia, Australia and North America has been enormous. United States trade has increasingly shifted toward Asia, relative to Europe, and now is approximately equal between Asia and Europe. As late as the 1950's, the United States' total trade with Europe was over 3 to 1 to that of Asia, indicating the very rapid trade shift that has occurred for an economy as large as ours.

Puget Sound has also reflected this trade pattern shift. In 1950, with a large portion of our foreign trade being with Europe, we were considered from a national viewpoint, as the extreme Pacific Northwest "corner" of the United States. The international trade that flowed through our ports in Puget Sound was primarily for our local marketing area. This is "obvious" since we would not expect European cargoes to move via Puget Sound to the eastern seaboard of the United States. Our ability at that time to compete for cargo movements between large international markets was limited at best since U.S. trade with the Pacific Rim was "minimal."

Presently, however, because of the rapid succession of economic miracles throughout Asia, Puget Sound has changed status from a "corner" to the logical transpacific, Asian/North American, transshipment point. This is an international trade route that is now second only to the world's most voluminous, the North American/European transatlantic route. With the U.S. trade shift toward Asia has also been the rapid economic growth of the Alaskan community, as well as growth in our own local market. The end result is that we in Puget Sound, for the first time in our history, are in a position of obtaining the economic activity known as the "middleman" on a trading route between other, separated economies. Traditionally, we have provided maritime transportation services primarily for attracting new industrial, agricultural and forestry activities. Now we are in a position to provide services for moving cargo which clearly has the choice of a number of ports to transit on a route which has originated or is destined far beyond our own market. Thus, we are able to utilize the shifts of world trade patterns to our own advantage and foster a shipping industry that requires little additional drain on our region's financial and natural resources, yet greatly adds to the diversity and strength of our region's economy. Furthermore, because of our region's geographic advantages, we can compete with other ports and the Panama Canal at a minimum overall cost. The advantage of a higher volume of traffic at a lower overall cost is particularly important for our regional users of maritime shipping now that our trade situation is similar to that which New York citizens have enjoyed over the last century, the difference being that our local shippers are utilizing shipping services essentially being paid for by shippers moving cargo between Asia and the U.S. Midwest and East Coast, instead of Europe and the U.S. Midwest and West Coast.

I present this concept of the changing status of West Coast port shipping patterns primarily to illustrate our growing trade potential. We, in Puget Sound over the past few years, have become a seaport on which a large portion of our nation is becoming increasingly dependent. In effect we have become less of a coastal community merely utilizing a port for contact with the world market. For example, the choice of Puget Sound as the Trident submarine base was more than just a political decision, it was a logical choice from a national security locational viewpoint. We were not viewed as the corner of the U.S., but the center of North American activity in the Pacific Rim. Furthermore, as I have stated before and will restate now, the choice of supertanker traffic on Puget Sound may be one choice that will be made at a national level, unless we in the Puget Sound area view Puget Sound as a "national" seaport resource and come up with a workable compromise (of which there is at least one good one). For general cargo shipping, however, (which is the least costly maritime activity upon the environment, but which gives the greatest overall economic returns) we are in strong competition with other West Coast ports and Panama Canal for the Pacific Rim's traffic. Not so much within the Pacific Northwest, but with California ports. But that's the way competition works, the most desirable cargoes are also the most sought after. Thus, while the national government may answer some of our supertanker questions, almost every port on the West Coast is actively seeking the Asian general cargo traffic.

That's where we stand on the changing international trade pattern. What maritime commerce do we actually have in Puget Sound? Figures, as you are well aware, can be very misleading. For example, East Coast ports have been shipping in crude petroleum and delivering petroleum products for a long time, while on the West Coast we are just now relying on crude and product tanker traffic for a significant proportion of our needs. On the other hand, West Coast ports have always shipped significant amounts of wheat and forestry products. Thus, the statistics for overall tonnage essentially compare movements of petroleum versus a movement of wheat, lumber, logs, sand, gravel, etc.

Total Puget Sound tonnage has been running in the range of some 50 million tons per year, 53 million in 1975, a poor year for international trade. To put this into perspective, that's greater than the overall 50 million tons handled in the San Francisco Bay region and the 52.6 million tons in Baltimore and is approaching Southern California's 60 million tons. It is somewhat less than Philadelphia, New York and New Orleans, all running close to 150 million tons annually.

Furthermore, since we are also concerned with the ocean approaches to Puget Sound, we must consider our neighbors to the North in Canada. The Vancouver harbor alone has been handling approximately 35 million tons per year and neighboring Fraser River ports would easily raise this traffic to 40 million tons. A combined Strait of Juan de Fuca tonnage of both Puget Sound and lower mainland Canada could be reasonably approximated at over 90 million tons a year. That figure is greater than the regional totals for Houston's 84 million, the Virginia ports of Norfolk and Newport News, 67 million, and a little more than half of the nation's largest port, New York with its 178 million tons.

To put these comparisons into further perspective, the combined number of vessel calls using the Strait of Juan de Fuca is estimated at approximately 5,000 per year. This is equivalent to, or greater than, seven of the top eight U.S. ports, Philadelphia Los Angeles/Long Beach, New Orleans, Houston, San Francisco, Baltimore and Hampton Roads, Virginia and approximately half of New York harbor's 10,000 total.

So from a maritime commerce viewpoint, we are already a major port area, particularly if you include both Puget Sound ports and the ports of southwestern British Columbia. From almost any measurement, traffic in the Strait of Juan de Fuca is in the "world leagues."

Before commenting on the use of Puget Sound for oil tanker movement, I think it is essential that we put some perspective on the navigational safety factor as it affects vessel movement through the Straits and into upper and lower Puget Sound areas. Considering how the aforementioned statistics tend to imply "considerable navigational hazard potential" as a result of our positioning with the other major U.S. ports, it is most important that we emphasize our overwhelming advantage over other U.S. ports as concerns the natural navigational safety factors.

I know of no safer area on the North American continent than is afforded Puget Sound ports as a result of deep water and channel width access. And this natural asset to maritime commerce is not limited to the North American continent alone, but compares favorably with heavy traffic areas the world over.

The Strait of Juan de Fuca varies in navigational width, but is generally 12-14 miles wide. By comparison, the Strait of Gibraltar narrows to some 9 miles. The English Channel, one of the heaviest used waterways in the world, narrows to some 18 miles near Dover. Even the Strait of Malacca off Singapore, the major route between the Orient and Europe, narrows to some 20-30 miles. These straits have several times the estimated 5,000 vessel calls using the Strait of Juan de Fuca.

The so-call "treacherous" Rosario Strait into the refinery areas around Cherry Point is1- to 3-miles wide. By comparison, the Houston Ship Canal which also has nearly 5,000 vessel calls per year is a 50-mile long, 400 foot wide channel. Philadelphia's Delaware Bay channel, being utilized by something slightly over 5,000 vessel calls per year, is a 90-mile long, 800 to 1,000 foot wide channel. And, even the New York harbor with nearly 10,000 vessel calls per year has only a 600 foot wide channel into the harbor from the Atlantic Ocean.

Furthermore, our waters are not only exceptionally wide, but exceptionally deep all the way into our harbor areas. The minimum depth into Seattle, for example, is 175 feet at a width of some two to three miles.

Only with complex and expensive dredging into the continental shelf or the construction of expensive sea islands can depths of over 50 feet be accommodated on the Gulf and Eastern Seaboard, south of the State of Maine. The highly publicized Maine superport tanker sites may be double this depth, but they have relatively winding and hazardous approaches. On the Pacific Coast, the country's second deepest port is Long Beach which is being dredged to 62 feet, though the narrow continental shelf would allow a relatively easy deepening to nearly 80 feet. San Francisco is limited to approximately 50 feet because of the troublesome sandbar off Golden Gate.

Therefore, the Puget Sound depth advantage, with the largest modern bulk cargo ships drawing over 100 feet draft, is not a small advantage, but the only viable, onshore, protected, continental U.S. deep-water port site. This natural advantage is not to be taken lightly.

Because of our environmental concern over growing general cargo tonnages and additional oil tanker traffic on Puget Sound (and a heavy push by Senator Magnuson, I might add), we have added to the natural safety factor by the implementation of a vessel traffic navigation program now being administered by the U.S. Coast Guard. I must admit we had a tough time convincing the federal government that we needed a lane separated, radar controlled ship navigation system, when places like Houston, Philadelphia and New York, whose channels are measured in <u>feet</u> not <u>miles</u>, did not have such a system, but it does serve as a creditable example of how we in the maritime industry are doing our part to see that our use of Puget Sound doesn't spoil it for others. I do not want to imply that we neither need, nor should improve, navigation vessel control in the Strait of Juan de Fuca and Puget Sound. There is still more to be done, such as extending the aforementioned system past Port Angeles into the Pacific, an extension into Northern Puget Sound and joint Canadian cooperation in the system.

From a national standpoint, I think the implementation of navigational safety programs is a worthwhile investment, from a regional viewpoint, a very wise investment. We here in the state of Washington are appreciative of this natural resource known as Puget Sound. Its multiplicity of uses for industry, transportation, recreation, fishing and, increasingly, mariculture needs all the protection which can be logically afforded. The wise management of this resource is dependent upon the interaction of all its users.

In closing, I would like to address my remarks to the earlier promised matter regarding the use of Puget Sound for oil tanker movement. It is my strong feeling that the current controversy over the movement of crude oil from the new Alaska pipeline and other offshore oil sources through the Puget Sound area has distorted the real facts. These facts have to be seriously considered before any potentially restrictive legislation is imposed. I refer to two specific considerations, first, the fact of existing tanker traffic on Puget Sound and, second, the fact of viable and safe tanker unloading site alternatives for a common oil port.

As regards the first consideration, arguments used by opponents of oil tanker traffic on Puget Sound confuse the public as a result of an inference that tanker traffic would be something new to Puget Sound waters. The fact is that there has been regular and consistent oil tanker traffic on Puget Sound for more than half a century.

The primary destination of these tankers is the Anacortes and Cherry Point refineries, and locations in Southern Puget Sound ports of Seattle and Tacoma. During 1976, 475 oil and product tankers delivered 213,078 barrels per day of crude oil to northern Puget Sound refineries and approximately 75,000 barrles of product, mainly to southern Puget Sound.

The cut-off next year of the primary source of crude, the Trans-Mountain Pipeline from the Alberta oil fields, will mean a near ten-fold increase in crude oil traffic on northern Puget Sound— from less than 2 million tons in 1972 to over 17 million tons in 1978 required to meet Northwest consumer needs only.

If we are required to accept additional traffic for needs beyond our own, it should be handled at a common unloading facility under the safest conditions possible. Considering the fact that safe, deep-water port access is beginning to be recognized by national policy makers as a "national resource," we cannot turn our backs on landlocked users of crude oil by failing to keep national policy in mind. If each area considered only their own interests, where would we be? We get oil from Texas, Louisiana, California and Alaska. Where would we be if residents of these states thought only of themselves? We need each other and we have to understand that Puget Sound belongs to more persons than just Washingtonians.

I am not saying that we should accept the transshipment of crude oil responsibility without seeing that our own conditions are met. That's why many of us in this industry have and will continue to fight long and hard to get federal assistance in the implementation of special navigational safety programs. It is the way we get the upper hand in guaranteeing all residents of the Northwest that Puget Sound will remain open and safe for the enjoyment of all.

Puget Sound does have viable tanker site alternatives to the existing Anacortes and Cherry Point refineries. Port Angeles is an excellent example. It provides deep-water access and sheltered protection from heavy storms, the key considerations in the safe movement of oil tankers. Oil can be safely moved from that area either south around Puget Sound and then northward to existing refinery sites, or perhaps even safer via an underground pipeline from Port Angeles to present refineries.

The safety of underwater transmission of crude oil, by the way, is a proven fact. In 1953, the Interprovincial pipeline was installed between the upper and lower Michigan peninsulas under the Straits of Mackinac, separating Lakes Michigan and Huron. This represented the deepest underwater pipeline crossing ever attempted and is one of the world's major pipeline feats. At the crossing, the U.S. straits are 4-½ miles wide and up to 240 feet deep. The two 20" lines made of steel one inch thick are still in use.

I trust that today's comments have not wandered away from the purpose of this symposium. It has been my intent to clarify the needs of maritime commerce on Puget Sound and the safety in which that industry can be carried out.

It is my opinion that a strong understanding of each on the part of the public will prevent anyone from ever having to worry whether or not imposed regulations and laws are too restrictive.

TIME AND CHANGE IN PUGET SOUND

Richard H. Fleming
University of Washington

My comments will be from the perspective of a teacher rather than that of a research investigator. As a professor of oceanography, my major concern has been to organize and simplify a wide range of topics concerning the science of the sea. In recent years as a member of the faculty of the Institute for Marine Studies, I have had to broaden my interests to consider how the marine environment affects the human population and more particularly how the environment interacts with human activities and technologies. These effects are always two-way processes: first, how the environment directly and indirectly influences human life and activities; and, second, how these, in turn, tend to alter or affect the environment. In a coastal region, such as the Puget Sound area, where there is a relatively large and increasing population living near its shores, it is obvious that many land-based activities must be involved and should be treated as components of the environmental system. It is from this perspective that I wish to discuss a few topics concerning the use, study, and management of Puget Sound.

THE ENVIRONMENTAL SYSTEM

According to my dictionary (Random House, 1967), environment is defined as "the aggregate of surrounding things, conditions, or influences especially as affecting the existence or development of someone or something." This definition is all-inclusive but does not adequately stress the complexity of the system nor the fact that the various "things, conditions, or influences" are variable in both space and time. It is this variability that makes the environmental sciences, which focus their attention on living or inanimate features of our planet, different from the laboratory sciences or basic sciences which strive to describe the characteristics and behavior of matter and energy in terms that are independent of both location and time.

Many of the aspects of the environment can be identified under the general topics of _what_, _where_, _when_, and _why_. This mnemonic list can be applied to any aspect of the environment, but it serves especially well when dealing with the environmental characteristics of a particular region. The _what_ serves to identify the lengthy list of features and characteristics that can be identified, observed, measured, or deduced. This list has been increasing as our abilities to observe and measure have improved. The where is to remind us that most of the items in the list of whats are not uniformly distributed but vary in three-dimensional space. The space that we are concerned with is usually defined in terms of location on the globe (latitude and longitude) and either depth or elevation (usually related directly or indirectly to mean-sea level or to some other datum). The when is to indicate that all aspects of the environment change with time. The why is to remind us that we must seek to identify and evaluate the processes that produce and control the spatial variability in the features and characteristics and that govern their variability in time.

The what, where, and when provide the information necessary for a description of an environmental system and much of the material can be accumulated by systematic and repeated sets of measurements, which are generally identified as surveys or monitoring or, if the interest is upon how the characteristics vary with time, as time-series measurements. It is only from such comprehensive studies that we can identify the nature and magnitude of the spatial variability and determine the character and scale of the changes with time.

The fourth mnemonic why represents the primary interest and role of the scientist. Although the scientist may play a role in the development of new techniques of observation and measurement and in testing these methods in the field, his primary responsibility is in identifying and evaluating the processes that control or affect the space and time variability of the features and characteristics. This is a far more difficult task than those associated with the description of an environmental system. In part this difficulty is due to the fact that most features can be altered and affected by many causes and any one cause may be related to many different effects. The inherent complexity of environmental systems makes them both challenging but often frustrating subjects of study.

The goal of the environmental scientist is to develop dynamic, integrated models that will serve to explain the time and space variability. These models may take various forms and content. They may be physical models (such as the model of Puget Sound which reproduces many of the features of the tides, tidal currents, and the effects of dilution), or they may be mathematical or numerical models which can be handled by a computer. Such models are generally limited in content or are not adequate because of lack of knowledge of the role and magnitude of the processes that are involved. Although none of the existing models is entirely satisfactory, it is only through the application of modeling techniques that we can ever hope to achieve an adequate understanding of the Puget Sound system.

I have not made any attempt to define what I mean by the Puget Sound environmental system. In the first place, it will be necessary to recognize that it cannot be limited to the salt water. It must include adjacent land areas and the atmospheric conditions that are represented by the climate and weather over the drainage basins that form the watershed for the region. Last but not least, the system must include the human population and the many types of activities in which they participate. These too are parts of the environmental system and must be treated as components in the model and the consequences of their activities or processes that tend to modify the environment.

THE TIME COORDINATE

There are three general objectives common to the environmental sciences: To understand the present; to interpret or reconstruct the past; and to predict the future. These objectives serve to direct our attention to the time dimension and to the recognition that we are dealing with a continuum of time. The major utility, that is practical application, of environmental science lies in the ability to project or predict future conditions.

In the previous section it was pointed out that one of the tasks of environmental scientists is to determine how the various features change with time and to identify the nature and magnitude of the processes that produce these changes. In some cases the rates of change are so small that it is reasonable to assume that the rate of change is zero. This is the assumption that is made concerning the gross features of the topography of the land and the submerged topography of the sea bottom, and it is on this assumption that we accept and use topographic and bathymetric maps. Another type of change is that represented by the tides and tidal currents. Although both of these features are characterized by high variability in both space and time, they can be related to the relative motions of the earth, moon, and sun and hence can be predicted with reasonable accuracy on the basis of previous measurements and the appropriate astronomical data.

Many other features, particularly those that are related directly or indirectly to the atmospheric conditions, are much more difficult to predict. This is in part due to the fact that the weather and climatic conditions themselves cannot yet be adequately predicted. Much can be learned about the interactions that occur between the atmospheric conditions and other components of the environment by systematic studies over time. General seasonal and annual averages can be obtained, but more valuable insight can often be derived from the investigation of year-to-year differences and in the study of extreme events.

The waters of Puget Sound have been studied for about 45 years. The data are often fragmentary, but they provide at least a first approximation of the space and time variability. This type of study has largely been replaced by investigations that are more specialized in content or more localized in space or restricted in time. Although some are motivated by scientific interest, it is also apparent that many of these studies are undertaken in order to answer specific practical questions. Although the recent level of effort is much greater than it has ever been in the past, the programs lack the content and coherence that would substantially improve our understanding of the area.

THE USE AND MANAGEMENT OF PUGET SOUND

The terms "use" and "management" of Puget Sound imply the presence of a human population and of their activities and suggest that it may be desirable to modify or control their number or the impacts that they have upon the environment. It is beyond the scope of this paper to attempt to list all of the ways in which exploitation of resources, industries, and other uses and activities can influence and affect the various components of the environment. In any analysis of these impacts, it is necessary to distinguish those that are population dependent, that is primarily related to the size of the human population and those that are technology dependent. Since the beginnings of the Industrial Revolution some 200 years ago, many new types of industries have been developed, and, at least in the industrialized countries, these have been growing at rates greater than the population. An extreme example of this is the utilization of energy from various sources. In the United States during the past century, the per capita energy production has increased by a factor of six. Because of the variety of relatively new industries, each of these must be identified and its direct and indirect environmental impacts evaluated. In the Puget Sound region, the rates of population growth have been more rapid than for the U.S. as a whole. The rates of industrial growth, both marine and those located upon its adjacent land, have also been relatively large. This can at least in part be attributed to the fact that most of the growth has occurred in a span of less than 100 years. The populations in the twelve counties that border on Puget Sound and the waters between Puget Sound and the Canadian border have increased as follows:

Year	1910	1940	1960	1970
Population (millions)	0.6	1.1	1.8	2.2

What these numbers indicated is that the population has nearly quadrupled in an interval of 60 years. These values were used by the Pacific Northwest River Basin Commission (1970) to project the population to be over 4 million early in the next century. A more recent projection by the Puget Sound Council of Governments is more conservative, but this too indicates continued exponential growth. I do not wish to debate the merits of these demographic projections, but they serve to illustrate my point that within the lifetime of our children the population will probably double over its present level. If we remember that the per capita level of industrial and other activities may increase at an even faster rate, it is easy to see that the magnitude of the impacts on the environment will, if not limited, far exceed anything that has so far been observed.

The purpose of these comments has been two-fold: first, to point out that in dealing with the impacts of human activities it is essential to consider what will occur over fairly long time spans and, second, to emphasize the importance of comprehensive and systematic monitoring programs. If we deal only with the natural features and processes, that is those which are not affected by human activities, our past experience may be adequate to project or predict future conditions. However, if we wish to include the impacts of human activities and if these continue to grow at exponential rates, our past experience is no guide as to what the future impacts may be. It is no reassurance that so far no obvious adverse effects have been observed and that it is therefore safe to relax and discontinue our studies.

CONCLUSIONS

1. Variability and change occur in all aspects of natural environments.

2. To adequately describe the characteristics and changes in environmental systems it is essential that comprehensive investigations be continued over long periods of time.

3. The processes controlling the distribution of characteristics in space and time must be identified and evaluated.

4. Quantitative models must be developed to provide reliable means for projections and predictions.

5. The human population and their activities, both on shore and afloat, tend to produce environmental changes. These impacts must be identified and incorporated in the predictive models.

6. Because the human population and their activities are increasing exponentially, the historical date are not a proper measure of potential impacts in the future. Programs of surveillance and monitoring of the conditions must be increased rather than curtailed.

SOCIAL SCIENCE PERSPECTIVES ON THE MANAGEMENT OF PUGET SOUND

William B. Beyers
University of Washington

The broad scope of this conference, encompassing as it does various levels of government, the scholarly community, industry, and citizens, makes it very difficult to define comprehensive answers to the questions posed by its sponsors. In my remarks, I am going to wear the hat of a social scientist. Thus, I will be primarily concerned with questions from the perspective of man, in contrast to possibly more naturalistic orientations which might be taken by scientists such as oceanographers or biologists.

The social sciences embrace a number of disciplines, with fuzzy disciplinary boundaries and divergent theoretical and methodological perspectives. It is not easy to encompass the perspectives of disciplines such as economics, sociology, political science, psychology, law, geography, history, and anthropology in a single talk. However, faculty at this University from each of these fields, as well as cognate disciplines not mentioned, have research, public service, and teaching involvement in the use, study, and management of Puget Sound. Given the physical proximity of the Sound to this University such interest is not unexpected, encompassing such divergent topics as the economic impact of oil spills, trends in the human use of shorelines, characteristics of our native American culture, the effectiveness of coastal zone management programs, the development of information systems for the management of shorelines, and an evaluation of how ports are integrated into coastal zone management programs. Although there is and has been much research by social scientists on Puget Sound, this work is not well integrated and it is not possible to find a convenient summary of multi-disciplinary findings. For example, one attempt at teaching a course at the University with such integrative objectives a few years ago was scratched due to lack of funds. The remarks to follow will probably be less comprehensive than they might otherwise be if such integrative studies had occurred.

Why do we have regulations or guidelines for the management of Puget Sound? Social scientists would provide several answers to this question, and let me suggest two broad areas of concern. First, Puget Sound is a common property resource, a resource which has value to many individuals or organizations who would like to extract this value for their own purposes, and who collectively would take more of these values than the resource can sustain. Without regulations governing the magnitude of individual and collective use, we could destroy the very resource values we prize. Second, Puget Sound is a quasi-public good. Puget Sound has values which we as a citizenry demand, but collectively without taxation or regulation we would not retain at desired levels of supply these public good characteristics. Both the common property resource and public good qualities of Puget Sound lead to difficulties in social and economic areas, such that regulations by governments at various levels for a variety of purposes have been enacted. Our fisheries management programs--controversial as they may be--are designed in part to keep us from overharvesting fisheries stocks such that they may perpetuate themselves at desired levels. Our water pollution control, zoning, public access and park programs, and marine traffic management systems could be viewed as attempts to assure that the Sound as a public good is managed appropriately.

These two concepts--public goods and common property resources--have been most elegantly developed in economics and political science--but also form the basis for considerable research in law, geography, and planning. I would like to argue that the models which have been developed and the regulations and laws which have been adopted as a result of this type of thinking have an anthropocentric flavor to them and have dominated regulation-making to the exclusion of other kinds of planning and alternative values. Thus, our laws and regulations have been developed by looking at the Puget Sound marine system largely from the perspective of man, viewing and interpreting the resource in terms of human values and experiences. This type of thinking has limits, because it ignores components of the environment which do not enter into the definition of public good or common property resources which become components of the objective functions for the system of regulations and guidelines used to manage Puget Sound. These neglected dimensions have little human value, as reflected in our socioeconomic demands for the Sound's resources. For example, we prize salmon highly and fight over property rights to the species, develop costly and complex propagation systems and catch regulations, but we have paid little attention historically to local cod and flounder property rights, catch levels, or propagation. While these latter species are harvested, they have certainly not been a central focus of our regulatory system because we as humans have not accorded them the same value as salmon. The same can be said of many other species of life and physical qualities of Puget Sound, including the seaweeds, currents, most resident birds, plankton, inedible crabs, thermal properties of the water, etc.

Thus far there has not been pressure by man to establish regulations to assure the conservation of these largely non-valued qualities of Puget Sound. There is no movement to achieve the equivalent of wilderness status for parts of its environment. While we may feel that we already have a hopelessly complex set of regulations, I argue that they pertain primarily to those chosen dimensions of the Puget Sound which we have accorded value either as common property resources or public goods in laws and regulations. Thus far we have not approached Puget Sound in our regulations as an integrated marine environmental system; we have not attempted to systematically conserve all of its features. Some species have all but disappeared because of this bias, such as seal, eagles, and various hawks. Intertidal life has been eliminated in many areas through filling, bulkheading, or pollution. Visual characteristics of the shoreline have certainly been altered, as we construct our monuments to human civilization. The degree to which these structural changes have influenced populations of birds such as heron or gulls is unknown to the best of my knowledge. Similarly, the impact of the clearing of natural vegetation from shorelines for settlement or other human purposes on either terrestrial or marine life is unknown.

These examples may seem extreme. They are not, for they illustrate that there are latent regulatory areas, that our current regulatory approaches are partial, and suggest that if we as a society change our values we will change our regulations to either encompass values now ignored or to discontinue regulating factors no longer of concern to us. The growing interest in geoduck harvesting may be an example of an area where regulatory need will arise. Books such as Incredible Edibles may help popularize the edibility of some relatively rare marine organisms, leading to their overconsumption and possible damage--in much the same way that the Mountaineers hiking guides have popularized certain places and contributed to their degradation through overuse.

Unfortunately, social scientists are unable to predict shifts in human values. Thus, we cannot anticipate the scope of regulations which might be necessary to encompass presently unvalued species or environmental characteristics. Tragically, our common approach is to wait until we experience a crisis or perceive such a degradation of value that we must enact regulations to protect common property resources or to keep or develop public goods to socially desired levels of existence. In this regard, our federal pollution control and coastal zone management laws, regulations, and programs may be viewed as responses to human needs; programs designed to restore to tolerable levels the quality of the marine environment, or as regulatory systems to assure we do not ruin a public good because of a lack of foresight.

As to whether the existing laws and regulations are doing the job intended, the preceding paragraphs give license to say both yes and no, as well as maybe, or I don't know. There can be no doubt but that our water quality programs and laws have led to reduced levels of effluent discharge and are associated with measured improvements in water quality in Puget Sound. The land acquisition programs of BOR and IAC have helped to bring into public ownership tracts of land on Puget Sound to meet the recreational needs of our growing population. These programs are not without their snags, and are only partially completed, thus making it hard to answer the question "Will these programs (like the myriad of other programs related to management of the Sound) ultimately achieve the legislative goals set down for the programs?" Thus, while in some cases we can observe movement in the right direction, it is hard to see where we are headed ultimately.

Social scientists are conditioned to situations characterized by flux in public values. Regulations and laws are in a constant state of change, not just because we change our values as previously discussed, but because technology changes, and because we find that earlier approaches were either unimplementable, inequitable, or inadequate. The nation's political system is designed to allow continuous adjustment in governmental programs, and this type of flux makes it extremely hard to assess how effective a program is in mid-stream.

We can be assured that if problems arise with present programs, or the lack of programs, we will develop new approaches to their solution.

The current debate over petroleum transfer systems in this state is an example of a marine environmental management problem in a state of flux. Existing state and federal programs and regulations are viewed from various quarters as either inadequate or too restrictive. The relationship between major and minor oil spills and federal and state water pollution control programs is undefined. The integration of new petroleum transfer systems into this state's coastal zone management and shorelines management programs is undefined. The regional wisdom and economics of additional petroleum movements are still being debated, while we are in the midst of "baseline" studies on the environments likely to be affected by any oil spills. These scientific studies designed to obtain an understanding of Puget Sound's oceanography, such that we could better evaluate what impacts would be on the natural environmental system of an oil spill will probably not be completed until after it will be necessary to make major oil transfer and petroleum processing policy decisions with possible far-reaching consequences for Puget Sound's marine environment.

Our coastal zone and shoreline management programs are also in a state of flux, with some calling for their strengthening, and others out to scuttle them. Are they doing the job intended? It is too soon to tell, as some work conducted at this University has shown. The program is just being implemented in many local jurisdictions, and the cumulative consequences of its implementation may not be observed for years. The consequences of these programs on the marine environment itself have received less attention than the implications for shoreline development, and most pressure to change these programs comes from those concerned with terrestrial rather than marine affairs.

While there is probably some legitimacy to the argument that current permitting procedures for coastal zone development are more complicated than necessary, it seems to me that within a given jurisdiction this is an adminstrative matter which can be solved and is unrelated to the larger purposes of the legislation--effectively the development of comprehensive land-use plans for the state's shorelines. As to whether the local plans which have been developed are unduly restrictive or too lax, again we are not in a position to judge, for they are too new. The program has forced some new development from shorelines, on the theory that shorelines are a relatively scarce resource in comparison to all land and only shoreline-dependent use should prevail, a theory valid in terms of acreage or square mileage. However, it is too soon to say whether the systematic influence of the adopted Master Programs will substantially relocate development in the Puget Sound region, or will systematically alter land values for various types of shoreline uses. Similarly, it is too soon to identify quantitatively in an aggregate way the marine environmental impact of these new programs. Qualitatively, their conservation bias seems to imply that many regions will remain in a more natural condition than would be the case without these laws, thus helping to preserve critical habitat areas with consonant positive impacts on the related marine environmental system. The same could be said of terrestrial environmental protection laws, to the extent that they indirectly affect the Puget Sound marine environment (such as the Forest Practices Act, SEPA, NEPA, etc.).

One of the major issues which the state must address as a result of all the local shoreline Master Programs is their collective nature and impact. The process of developing the master programs was highly decentralized, with no higher level evaluation as to whether the areas committed in aggregate to (for example) urban-industrial types of use (which generally involve substantial disturbance of adjacent marine environments) are too great from a regional perspective. If this is the case, the degree of indirect protection the legislation was designed to assure for the marine environment has not been achieved, and some rationalization of the local plans is needed. The cumulative impact of many relatively low intensity types of shoreline uses, such as residences, also needs to be assessed. Unfortunately, this type of assessment is not required in the State Shoreline Management Act. The state shorelines management program also seems to me to be biased towards considering appropriate land uses in certain areas without adequate concern for the individual parcel and the cumulative impact of these uses on the near-shore marine environment. Now that we have essentially completed the master program planning process for shoreline management in the Puget Sound region, what system will and should we have for the evolution of these plans, and how should we evaluate the performance of the Master Plans? How should any regional or state level analysis of the several local plans be conducted and possibly lead to rationalization of the local plans? How should we relate these CZM plans to characteristics of the marine environment?

Each of the questions just posed has several answers, although they will only be addressed when and if there is sufficient public pressure to do so.

The seemingly permanent nature of the shoreline Master Programs must be accommodative of change, and it may well be that the regional zoning of far more land for urban-industrial purposes than is likely to be used even within a century will provide the needed latitude for us to avoid the adoption of a required Master Program planning cycle of, for example, 5 or 10 years. (It is recognized that Master Programs can be revised by individual governments should the need arise under current law.) However, carrying this excess invites spotty development, over-investment or premature investment in infrastructure (such as bulkheads, landfills, etc.) with possibly adverse financial impacts if anticipated development fails to materialize in a program subject to long-term amortization.

It does not appear as though the state government can or should independently undertake a regional assessment of the various shoreline master programs. Instead, I would urge that the state should facilitate discussion of these plans at the regional scale, attempting to relate aggregate quantities of shoreline designated as available for various uses to projections of need for these aggregate amounts of shoreline. An input-output system of the type to be discussed by Richard Conway at this conference could possibly be used to obtain the estimates of regional need or demand for shoreline to be used by various sectors and households, coupled as such a model is to medium and long-range forecasts of economic and social activity. However, the data requirements and model specification problems for relating a typical Leontief-type input-output model to an essentially linear type of land-use with great variations in intensity of use available are significant. The various local government jurisdictions could coordinate the discussions of alternative local allocations of classes of shoreline use and estimated regional demands for such shoreline uses. These governments could articulate possible sequences for changes in use, in contrast to the present static nature of the Master Plans.

The state should also take the leadership in improving our knowledge of the interdependence between shoreline/coastal zone management programs and the Puget Sound marine environmental system. In effect this could be done via cooperative efforts between the Department of Ecology, Department of Natural Resources, Department of Fisheries, Oceanographic Commission, and other federal, state, and local agencies. A program of this type could and should be tied to research institutions such as this University and NOAA, and hopefully the results of basic research efforts such as the MESA program can be tied to man-oriented coastal zone programs.

It seems that we social scientists have a propensity to operate at a scale of generalization which is several orders of magnitude above that utilized by natural scientists, making it very hard for either group to integrate information utilized by the other group. If the state government is really concerned about the relationship between people and the marine environment of Puget Sound, and if there is this barrier to communication between scientists also interesed in Puget Sound, it should support research which increases the prospect of fruitful (policy-oriented) interaction between different types of scientists. The Sea Grant program at this University is an example of a place where research on such integrative approaches should be possible. However, unless there is a perceived public need to protect a public good or a resource of common value to all of us which is endangered because of either our ignorance or neglect, this type of research will not occur here or anywhere else.

I can assure you that the people of this state were quick to point out the value they attach to Puget Sound in the Alternatives for Washington program. In many different regions of the state, as well as with respect to many different types of use of Puget Sound, they were concerned not only with the maintenance of the quality of the environment, but also with the development of Puget Sound as a marine resource which can contribute to our economy. They supported this enhanced economic role for the Sound with the proviso that it not lead to environmental degradation, like that which frequently accompanies heavy industry such as petrochemicals, heavy metals production, or petroleum transfer facilities. In short, if this public preference polling is to be reflected in public policy, and it should be in a democratic society if the results are arrived at in an unbiased manner, which I believe they were, then it is clear that the people of the state will support our coastal environmental laws and regulations.

While our existing regulations for the management of Puget Sound as a public good and common property resource are imperfect, they are probably moving us in the desired direction. We can expect that these regulations will be continuously adjusted as society changes its values or perceives new needs or problems, as scientists refine their knowledge of the Sound's environmental system, and as technologists innovate new ways of using or relating to Puget Sound's resources. Frequently these changes will occur before we know the effects on man or the marine environment of the old ways. Hopefully, Bish <u>et. al.</u> were right about the adaptability and performance of the mechanism we have invented and will invent to cope with these changes, when they concluded an analysis of management programs for Puget Sound written several years ago as follows:

> . . .the conclusions here must be that humans, whatever their values and preferences, have done a reasonable job in creating an institutional structure for the governance of Puget Sound's resources that matches the diversity and complexity of the Sound's resource system and the uses that people make of it. This does not mean that the system is perfect or that it can or should stablize in a static form. Citizen access is extensive but participation is becoming more costly. Various subsystems have become more sophisticated in resource management and in recognizing their interdependencies but there is certainly more to be done. State and local governments tend to underinvest in relation to the Sound in management and regulatory functions in contrast to directly consumable public goods and services. Even so, the system has demonstrated a capacity for learning and continued evolution as new resource use preferences and conflicts have emerged (p. 198, Bish <u>et. al.</u>).

REFERENCE

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MUDDLING THROUGH THE MANAGEMENT OF PUGET SOUND

Brian W. Mar
University of Washington

It is difficult to prepare a paper that will anticipate the views of eight previous speakers in the same topic and hope that it will contribute something that was not said. Furthermore, as an outside observer of coastal zone management activities, it is easy to look at only a small part of the issue and not realize the complexity of this problem. As the issue was defined for this panel, I find two key works--restrictive and rationale--of special interest for my remarks. In the face of increasing demand there does not seem to be any way to conserve and protect the environment without being unduly restrictive. For example, to protect any resource whether it be a flowering bush, a beach with abundant intertidal forms, or a natural delta, it must be realized that these are natural systems with physically limiting regeneration mechanisms. A flowering bush can be stripped of all flowers by passers-by, if each wants a flower for his or her own use. Removal of anything at a rate faster than it can be produced will deplete the resource, and introduction of a large enough perturbation to the regeneration process will prevent the maximum production of the resource.

Since there is only a fixed resource in the coastal zone, the more ways it must be shared, the more restrictive regulations and guidelines must become if any form of equity is to be maintained. In almost all natural resources, the regulation of the use must focus on changing types of use rather than just rationing among one particular use. Consider a hypothetical example of the discovery of a bush that has pods that contain diamonds rather than beans. Natives have found that it takes all the energy a person has to get to the bush and remove one pod. Since diamonds have only ceremonial value to the natives only a few pods are harvested each year and the rest remain on the bush. One day an explorer stumbles upon this region and learns of the diamond bush. As the word spreads external pressure to get to the bush increase. In the mean time, this same series of events have been repeated in four other parts of the globe. The first group of natives have somehow acquired an economist as an advisor and have established a free market for rights to enter their land and travel to the bush. The price for rights increases as the demand increases. Unfortunately, the delays in information concerning the number of pods remaining on the bush and the response of demands caused the bush to be stripped before prices could be raised. Since the income from the rights had not exceeded the economists' fee the natives received nothing for their efforts

The second group of natives acquired an ecologist to study the bush and provide information on the regenerative capacity of the bush, the ideal environment to cultivate the bush, and determine maximum sustained yields prior to taking action. After forty years of study the ecologist concluded that there were only 5 bushes in the world, that the bush blooms once every 500 years but does not reproduce, that the pods remain on the bush 40 years and then are oxidized to CO_2. The tribe now is wiser, but must wait 500 years to benefit from this knowledge. In the mean time 50% of the men have been killed in actions to prevent harvesting of the pods during the time research was proceeding.

The third group of natives retain a lawyer who suggests the natives pass regulations: 1) that require any one traveling to the bush to file an impact statement, 2) that requires each tribe to develop a master program to define where wars, hunts and ceremonies can occur, and 3) that requires that separate tribal councils be formed to review each of these regulations. Since the level of knowledge was low on the relationship of the proposed activities and the response of the bush, the approved actions and plans permitted 2 subchiefs to harvest all the pods since they had the power to enforce the threat to eat any one venturing near the bush.

The fourth group of natives retained an engineer who argued that by building a new road, any native can easily travel to the bush and gather many pods. The engineer indicated that for 15% of the pods harvested they would gladly construct the road. Unfortunately, the construction crew caused a land slide which exposed a seam into a nearby volcano and the bush was destroyed by molten lava before any pods could be harvested.

The fifth group of natives successfully resisted all outside experts, and used the bush as a sacred symbol to be viewed but not disturbed and enjoyed the viewing and worshiping at the bush for 40 years until the pods disintegrated. Unfortunately, during this period severe droughts and other natural hazards destroyed the food resources of the region, and the natives lacking foreign exchange to purchase food found that 90% of their people died of starvation.

What this hypothetical series of natural resource management suggests is that 1) if harvesting begins, the tendency will be to overharvest and the demand will build until only a very small group can participate (since harvest technology will soon exceed the ability of the resource to sustain higher levels of harvest). On the other hand, if it is not used at all, the economic values foregone may be substantial. This is all too obvious in the case of fish, shellfish, drift wood, and even sitting on the beach in many parts of Puget Sound. In many of these resources, the demand to harvest or remove becomes so great that it must be prohibitive. People must change their use from one of consumption to one of anticipation, pursuit, or observation. The entire population cannot dig clams or fish on Puget Sound to supply a major fraction of its food supply any more; it cannot, even in many cases, fish for trophy-sized fish, one must be content to view the natural coastal settings, to look but not touch, since touching by many would destroy. In many cases the viewing is so crowded that there may be little difference between sitting in the domed stadium and sitting on the beach. With the potential of increasing demands how can regulations not be restrictive and how can but a few benefit?

To the lower income section of the population, what good are coastal zone regulations that protect the natural environment for the elite few who can enjoy it? How can one enjoy access to the shoreline when one cannot get to the access point? What evidence has been gathered to determine that if the natural environment is protected, the wealthy from all over the world will still not overrun the resource?

Since science can do little to answer these questions before the resource is depleted, one should question the wisdom of planning (which requires almost full knowledge) and a scientific basis for decision-making. The conventional wisdom seems to indicate that we have and will continue to muddle our way through coastal zone management. Muddling is defined as the process where an action is taken and then if no objections occur further action is taken in the same direction. On the other hand, strong reaction to any action should result in retracting the action and trying something else. In the case of coastal zone management the trend seems to be to continue to introduce regulations that further restrict the ability of anyone or any group from changing the status quo. It also suggests that scientific information can help the management process. In hindsight, the creation of DOE provided a mechanism to protect the coastal zone, yet SEPA was adopted to be more specific; subsequently SMA and CZM regulations provided additional actions to focus on the coastal zone. While each of these actions creates more hurdles to cross before activities can occur on the shoreline, they do little to address the real issue of how to equitably share the limited resources that exist. This may suggest that only those with enough resources to pass the hurdles can qualify (which is not a satisfying answer).

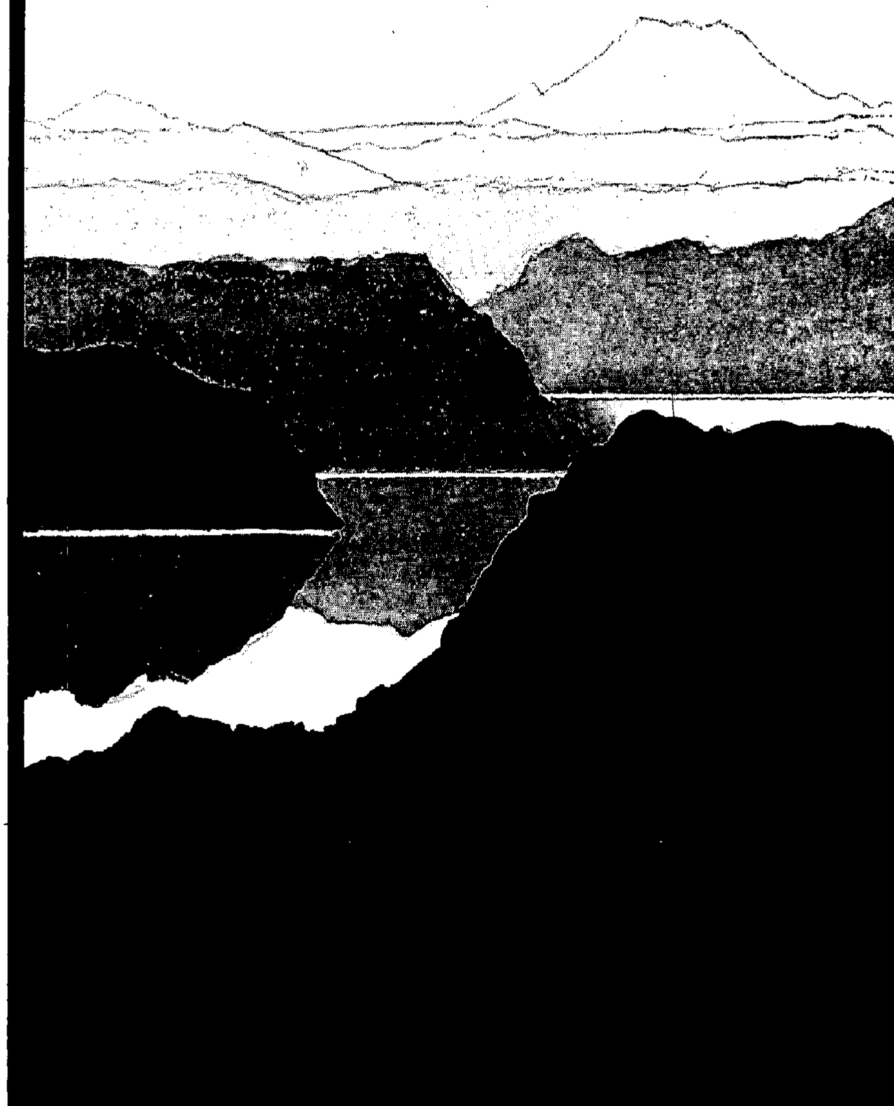
A common thrust of most regulations has been the requirement for citizen participation or local involvement. This seems to be another muddling action for decision makers who have lost contact with their constituencies and are seeking alternative ways to hear from the troops. People are tired of serving in citizen's groups because officials cannot find alternative ways to define where the pressure groups are and how they react. If they have to serve on a citizen's group for each governmental action that has major impact on them, they would not have time to attend all the meetings even if they gave up eating, sleeping and working. I would encourage the rapid passage of regulations until major revolts are encountered. I sense little revolt in the coastal zone area, so more regulations may be in order. I do sense revolt in citizen participation requirements since many of the active citizens are becoming weary of the time demands of such efforts and the lack of major benefits. We need to muddle in a new direction and some are suggesting mediation.

My early concern for the impotency of science needs further explanation. Science can only define the limits of the resource and its sensitivity to management action but science does not address the difficult question of how to allocate the resource. Allocation is a matter of values and perceptions, a topic that has not yielded to science. Thus overemphasis on science and the ability to forecast future actions or impacts of such actions may not be significant in the regulation process. It just presents an additional hurdle where a scientist can be retained by opposing interest groups to argue their ignorance over the issue at hand. Can science tell us the limits of the coastal resource any better than we know it today? Can this added knowledge make much difference in the way allocation of the resource is made? I would agree that it can for a selected few, but it does little for society as a whole. If we have enough people concerned about impacts of actions, we should listen more to their concerns. It will be a value judgement when the reaction is loud enough that action is necessary. Much of the coastal zone regulations are still in response to the environmental reactions of the 1960's. The energy, economic and employment concerns of the 1970's will probably shape the subsequent actions away from preservation.

As I indicated earlier, the limited amount of coastal zone resources compared to the staggering competing demands that will develop for these resources, seems to dictate only two equilibrium results; either it will be preserved on a "look but don't touch basis" where no one can use it (since use would result in serious degradation) or it will be exploited and consumed till it has little of the natural features remaining. Whether the transition from the current status to either end point will be fast or slow will depend on more than regulations; it will depend on the people selected to administer and develop such regulations. I hope they will develop their ability to react and observe the reaction of elements of society. I sense in reviewing the actions to date that many are jumping the hurdles established by regulations, but no one knows where they are going or why they want to win. Like the natives seeking to protect their diamond bush, can we protect the coastal zone or will our actions accelerate its degradations? The regulations can protect us from the known, but it is the unknown or the forgotten that continually creates problems in resource management. Science or muddling is no match for the unknown if demand cannot be controlled.

How should use limits
be established?

RESEARCH VIEWPOINTS



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AN INPUT-OUTPUT ECONOMETRIC MODEL OF THE PUGET SOUND REGION: A SUGGESTION

Richard S. Conway, Jr.
University of Washington

What is the impact on the Puget Sound economy of expanding facilities of the Port of Seattle? What is the appropriate development of shorelines given the pressures of regional growth? What will be the nature and source of future pollution affecting Puget Sound? These are examples of the many questions that face citizens, government officials, businesspersons, and academicians as they plan for the future of Puget Sound.

Common to the three questions asked here is the fact that underlying each answer is some forecast of the regional economy. How an expansion of the Port would affect the Puget Sound community would in part depend upon the resulting direct and indirect demands placed upon the local economy for goods, services, land, labor, and capital. Shoreline development plans would have to entail projections of the growth of industry, income, and population, among other things, since shoreline management involves the reconciliation of the industrial and recreational needs of the public. Similar projections would also have to underlie forecasts of pollution in Puget Sound.

An input-output econometric model is designed to provide the long-run economic projections required to address these and similar questions. With an explicit but flexible structure, comprehensive and detailed coverage of key economic variables, and internally consistent forecasts, the model is in general an effective framework within which to conduct regional economic analysis.

THE STRUCTURE OF THE MODEL

There are a variety of regional forecasting models, some much less complex than the input-output model described in this paper. The question arises, why not employ them instead? The correct response is that, indeed, a number of forecasting tools should be made available. Which one to employ depends upon the particular problem at hand. For example, if we require an estimate of expected regional income, a simple extrapolation of past incomes may well provide acceptable precision in many instances.

However, an econometric model with an input-output core is potentially one of the most powerful forecasting tools available. Its distinguishing attribute is the explicitness with which it presents the structure of the economy. Not only does this structure permit the projection of a large number of economic variables in an internally consistent manner, but it gives insight into why economic activity is at one level and not at another. By the same token, forecasters can address questions regarding how the economy might respond to a change at some point in its structure, such as an increase in its exports. Impact questions such as this commonly confront regional decision makers.

The broad outlines of the regional forecasting system begin to emerge in Figure 1, which indicates the major lines of economic force operating on the Puget Sound region. For modeling purposes, these lines are assumed to be uni-directional, running from the U.S. economy directly and indirectly (through the state economy) to the region. As such, the economic behavior of Puget Sound is viewed as being conditioned largely by its external economic environment. Feedback effects from the region to the state and to the nation are present, but from a forecasting standpoint, they most likely are of little concern, although this is a statement requiring empirical substantiation.

A more detailed depiction of a Puget Sound model is found in Figure 1. The model itself is a system of linear and nonlinear equations, which is designed to explain, or predict, the long-run interrelated behavior of many economic variables. The simultaneous solution of this equation system in a given year constitutes the set of predictions for that year. The individual equations can be conveniently grouped into blocks, or sub-models. These blocks and interconnecting linkages shown in Figure 1 describe the fundamental logic of the regional model.

Following export base concepts, the model identifies two sets of economic demands placed upon the region, export (or external) demands and local (or internal) demands. The export demands are considered to be a primary driving force behind regional growth. Exports in this context are meant to include foreign exports, exports to the rest of Washington State and the nation, and federal government expenditures. Exports of regional industries are largely determined by the state and national economic environments. Specifically, industry exports are postulated to be related to the corresponding state and U.S. outputs, an allowance being made for increasing or decreasing shares of these external markets. Projections of state and national outputs in turn come from the WPSM model of Washington State and the INFORUM model of the U.S., both of which belong to the family of input-output forecasting models.

The local output required to support these external sales triggers the first set of internal demands, the interindustry demands. For example, the export demand for regionally produced aircraft establishes a chain of demands which affect output in the local electrical machinery industry and the business service sector, among others. The induced output in these industries in turn sets up further intermediate demands, all of which are depicted by the equations in the output block. It is not an overstatement to say that these input-output relations represent the heart of the model.

However, the linkages are far from completely specified. Industrial output and projections of productivity combine to predict the number of jobs in the Puget Sound

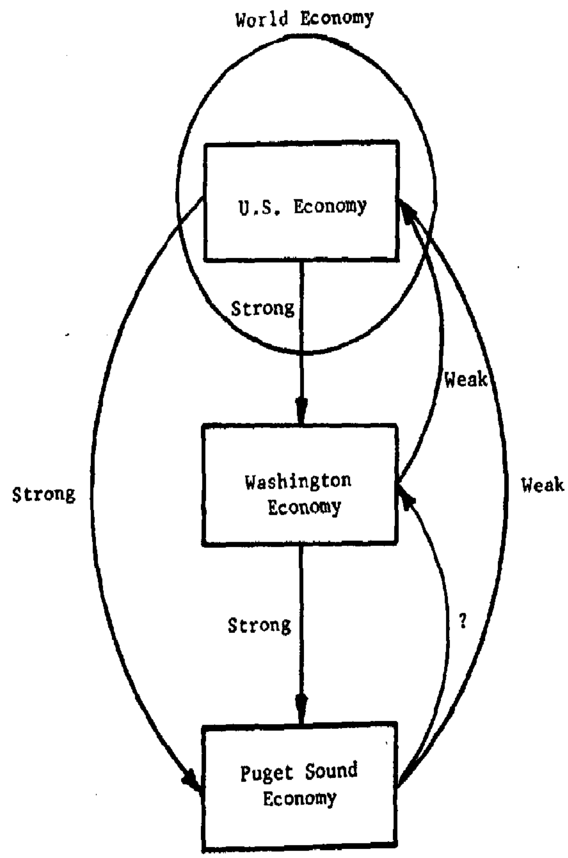

Figure 1

The Primary Linkages of a Puget Sound Model economy. This determines the number of persons employed, which, when coupled with predictions of unemployment and labor force participation, leads to projections of the labor force and resident population.

In the course of production, income is earned, primarily in the form of wages, salaries, and proprietors' income. Independent forecasts are made of property income, transfer payments, employer contributions to social insurance, and personal tax and nontax payments, which result in a determination of disposable income.

Disposable income and population together are key factors explaining the second array of internal demands, the final demands of the regional consumption, investment, and state and local government sectors. Consumer spending is related directly to the disposable income of households. Residential construction is linked to household income as well as to the current stock of housing, interest rates, and the cost of construction. Other private fixed investment is tied to industrial output levels, while inventory change is explained by changes in these levels. Disposable income also influences state and local government spending, but factors such as school-age population and federal highway expenditures also play a role.

At the same time that these feedback loops are operating, so called leakages are present in the system. These take the form of savings, taxes, and imports, and represent income or revenue that is not redirected into the flow of locally oriented demands. Although the model predicts personal taxes, it stops short of a complete specification of taxes and savings. On the other hand, the model does generate forecasts of imports. Despite the lack of attention paid to these variables, they are an important component of the system. Without the drain caused by taxes, savings, and imports, the flow of demand running through the feedback loop joining, say, output, income, and consumption would run interminably, causing the model to "explode" as prediction values grow to infinity. Speaking in mathematical terms, the leakages permit the system of equations constituting the economic model to converge to a solution.

APPLICATIONS

Uses of an input-output econometric model fall into two general categories, baseline forecasting and impact analysis. In the simplest case, the objective of baseline forecasting is to predict the future path of the regional economy. Obviously, we cannot know for certain what the next 10 or 15 years have in store for Puget Sound, but the model is a means by which we can reasonably predict likely courses of events. If there is disagreement over a particular set of projections, appropriate changes in the model (such as an alternation in the values of variables exogenous, or given, to the model) can be readily made. In this fashion, we can generate alternative growth scenarios for the region.

As indicated by Figure 2, baseline forecasts yield projections of many variables. For each industry, there are predictions of output, value added, regional intermediate inputs, imports, wages, salaries, and proprietors' income, employment, regional intermediate sales, and sales to final demand sectors. Other variables determined by the model include Gross Regional Product, total persons employed, labor force, unemployment rate, population, personal income, disposable income, disposable income per capita, personal consumption, residential housing investment, equipment investment, state and local education expenditures, state and

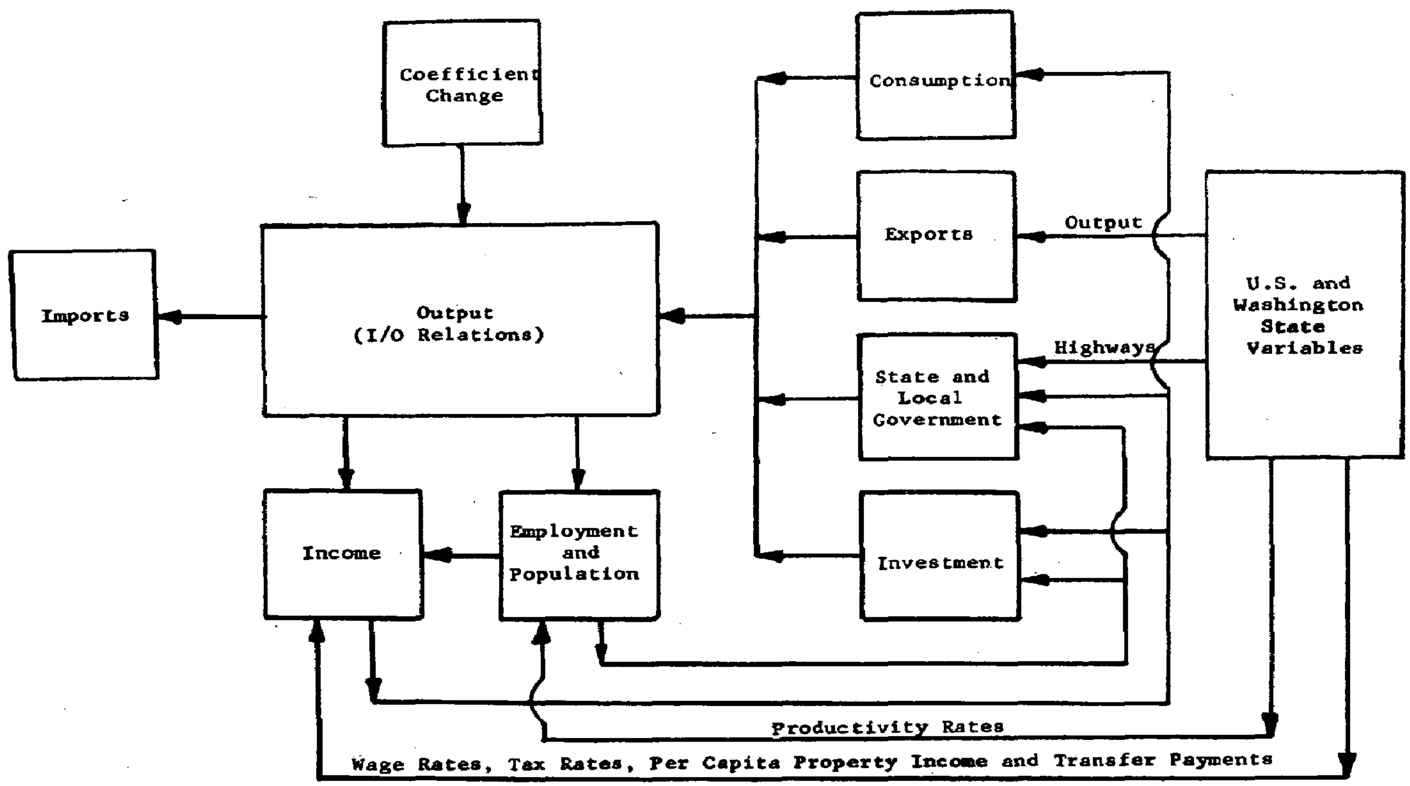

Figure 2

Puget Sound Input-Output Econometric Model local education expenditures, state and local non-education expenditures, and highway construction.

Nor does the list end here. Any variable, economic as well as non-economic, that is related to the principal variables of the Puget Sound model can be added to the system. For example, we can test for the existence of a relationship between waste residuals and output. If we find one, we can use the estimated waste residual coefficient or function to project future pollution in the region. In a like manner, we can also predict such things as water use, manpower requirements, energy consumption, land use patterns, and tax revenues.

The second major application is impact, or multiplier, analysis. The most common impact problem is the measurement of the anticipated effect on the economy of an expansion in the exports of some industry. Given a fully specified forecasting model, these impacts can be measured in terms of changes in Gross Regional Product, disposable income, persons employed, population, housing construction, or even kilowatt-hours. In fact, a multiplier value can be estimated for any of the variables endogenous to the Puget Sound model.

For those familiar with input-output techniques, we should point out that the multipliers of an input-output econometric model are conceptually superior to those of a typical static input-output model in at least four respects. First, the input-output econometric model is closed with regard to state and local govenment expenditures and investment; that is, there is an accounting of the feedback loops running through these two sectors of final demand. The output-income-consumption linkage is also more accurately specified than that found in static models. Third, the multipliers are dynamic in the sense that their values follow a time path as the various lags and time-phased adjustments operate within the system. Lastly, the model is not restricted to linear homogeneous functions and temporally constant interindustry coefficients, the latter being a chief concern among input-output practitioners.

THE FEASIBILITY OF A PUGET SOUND MODEL

Although the preceding discussion has been couched in the present tense, there is no input-output econometric model of Puget Sound at this time. A critical question therefore becomes whether such a model is feasible. Experience with national models and the Washington State model strongly suggests an affirmative answer, although further study of this question is certainly warranted.

As indicated by Figure 3, building a model of the Puget Sound economy would involve essentially two phases, the data-gathering phase and the construction phase. The most difficult and time-consuming step would be the collection of facts and figures necessary to implement a well-specified model. In comparison to published national information, the regional data base is thin and often of poor quality. However, there is good historical information on regional income and employment by industry. There is even a fair amount of data upon which to develop time series estimates of output. The biggest gap in the data base involves the final demand expenditures for consumption, investment, the services of state and local government, and exports. In this case, one could derive regional estimates from expenditures series developed for Washington State during the course of the WPSM

	Data Gathering					Construction		
	I/O Table	Final Demand	Output	Income	Employment	Development	Testing	
U.S.	X	X	X	X	X	X	/	INFORUM, Wharton, BLS
Washington	X	X	X	X	X	/	/	WPSM
Puget Sound	?		/	/	/			?

X = complete
/ = partially complete or readily obtainable

Figure 3

The Feasibility of a Puget Sound Model

project, an approach that would seem not unreasonable, since about two-thirds of economic activity in the state is concentrated around Puget Sound. As for an input-output table, we would have the choice of a table derived from secondary sources (such as the 1972 Washington State interindustry table), which could be estimated without much difficulty, or one based on a survey of businesses, which would be presumably more reliable but certainly more expensive.

Once the data were gathered, the actual construction of the model would be rather straightforward. Tinkering with the specification of the forecasting equations would be necessary, but the formulation of the Washington State model would provide useful guidelines. One last, but very important, step would be the testing of the model. Often, when analysts have an operational model in their hands, it becomes a toy; and little effort is expended in scientifically evaluating its properties of predictive capabilities. Since no model is an exact replica of the entity being depicted, it must be continually monitored and re-calibrated. Indeed, the job of regional economic modeling must be an ongoing one--that is, if forecasting is to be at all effective.

CONCLUSION

The strength of an input-output econometric model stems from its explicit structure, by which we mean that there is a clearly traceable line of logic underlying the relationships between economic variables in the system. As much as possible, this is an attempt to remove the mysticism pervading many of the forecasting models that have been built strictly on the grounds of statistical correlation. Furthermore, because of this structure, inherent in the model are a number of other valuable characteristics, including:

comprehensiveness

detail

consistency

flexibility

As a consequence, an input-output econometric model of Puget Sound would be a potentially powerful framework within which not only to make baseline projections, but to understand the intricate workings of our economy, especially with regard to how the economy would react to changes imposed upon it.

The major drawback of a Puget Sound model would be its cost. Such a model appears feasible, but it is also clear that its construction would represent a substantial research investment. However, given the importance of the problems facing analysts in our community, it seems more appropriate to ask whether we can affort <u>not</u> to pursue modeling of this sort.

SEDIMENTATION RATES IN PUGET SOUND AND THEIR APPLICATION TO HEAVY METALS POLLUTION

Ahmad Nevissi and William R. Schell
University of Washington

INTRODUCTION

Aside from being an important inland waterway, Puget Sound is the nursery ground for a number of commercially important marine organisms. Therefore, the natural balance of nutrients and trace elements in Puget Sound is important to the commercial and sport fisheries that have been established. Any imbalance in environmental conditions may alter the biological productivity of the marine life which would affect the fishery. In recent years, the residents and industries have expanded, and the disposal of wastes into Puget Sound, including trace metals, has increased. The key problem in the control of aquatic pollution is how to determine the amount of waste that can be carried by the receiving waters without damage to the marine environment.

Lead-210 dating of sediment cores is one technique for measuring sedimentation rates and establishing the age of recently deposited sediments. The basic assumptions behind lead-210 dating are uniform sedimentation rate, constant input of lead-210 into the sediment from the overlying water column and secular equilibrium between supported lead-210 and radium-226 over the last several hundred years at each location (Koide et al. 1972). Sediments are the sinks for heavy metals in marine environment and, thus, changes in concentration of heavy metals in the overlying water column with time can be indicated in sediment core profiles. The dating method, in conjunction with analysis of heavy metals in dated cores, have been utilized here in evaluating the history of heavy metals preserved in sediments over the past 10-100 years.

METHODS

Sediment cores were collected near West Point and Alki Point outfalls as well as other areas of Puget Sound using a 5-cm-diameter gravity corer and a 3.5-cm damped piston corer, equipped with plastic core liners. Sampling stations are shown in Figure 1 (note the sample numbers). Cores showing any disturbance of surface sediment were rejected; the selected cores were stored at 5°C until sectioning. In the laboratory the cores were cut into 1-cm sections and the outer 3-mm portions

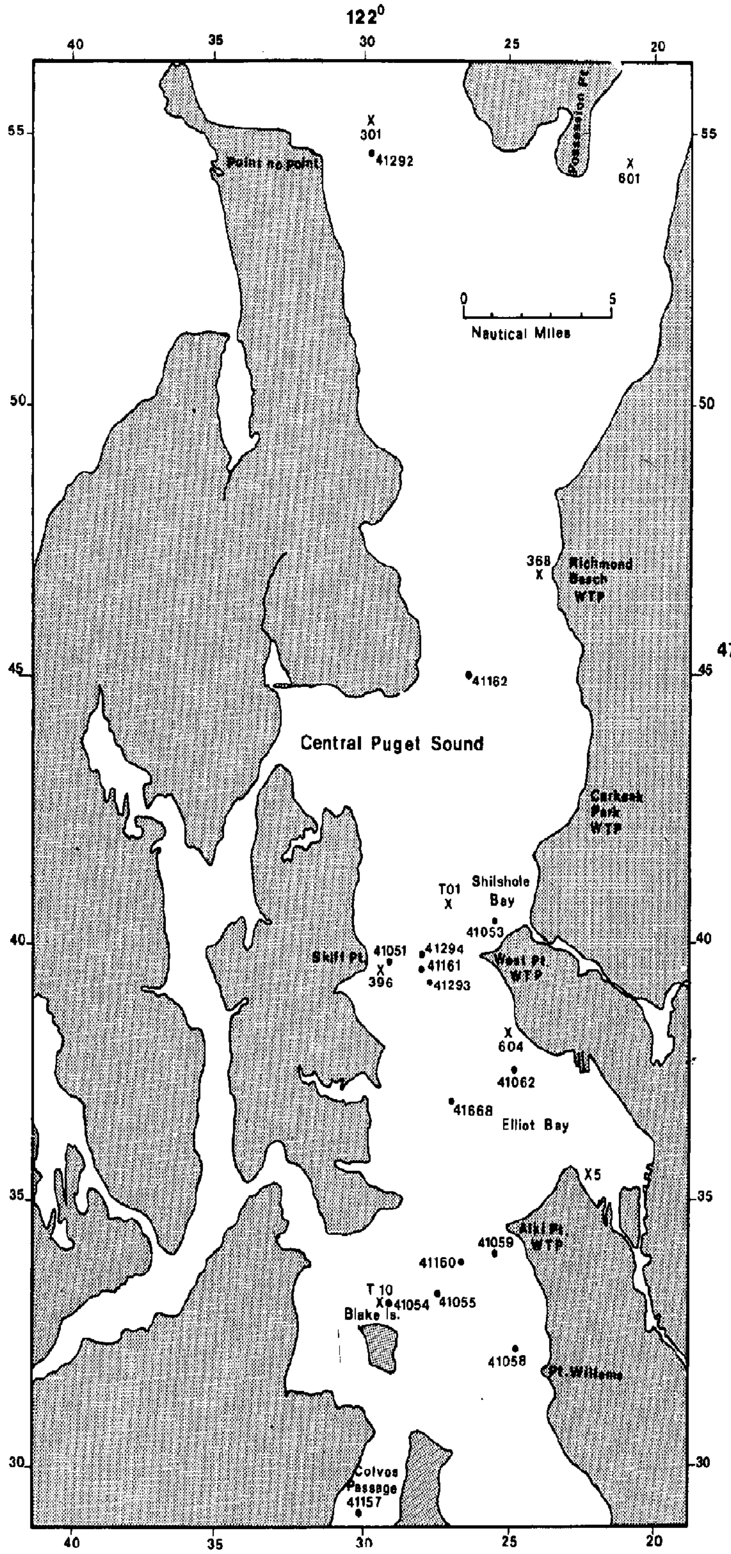

FIGURE 1. Location of water treatment plants (WTP) and sampling locations for cores, o, in central Puget Sound.

were removed; the sections were then dried, homogenized, weighed, and a portion of the subsample was spiked with ^{208}Po and was wet-ashed with distilled HNO_3 and $HClO_3$ (Smith 1953) for determination of ^{210}Pb and trace metals. Analytical details on measuring ^{210}Pb activity and trace metals concentrations are given (Schell and Nevissi 1977).

RESULTS AND DISCUSSION

An example of the values for a typical core profile for ^{210}Pb dating is shown in Figure 2. The heavy metals measured in the same core profile are represented in Figure 3. Other cores measured were observed to have a single or two distinct sedimentation rates from the several locations.

We have dated 14 cores from different areas of central Puget Sound by the ^{210}Pb radiometric technique (Table 1). The results show that there are wide variations in the sedimentation rates at different regions within Puget Sound (2-10.3 mm yr^{-1}). The input of ^{210}Pb and trace metals to sediment at each location in Puget Sound depends on the currents, sediment composition, biological activity in the sediment and the proximity of stream and river input of sand and silt from the land. The organic carbon content of the sediments and the sedimentological parameters (percentage of gravel, sand, silt, and clay) have not been measured in the cores used for this study. However, a granulometric survey of the marine surface sediments from the Strait of Juan de Fuca and Puget Sound was reported by Roberts (1974). By matching the core sampling stations from this study with the stations in the Roberts report, these sedimentological parameters were estimated as shown in Table 1. Considering the above factors, an attempt was made to compare the past history of trace metals deposition at each core location with the present concentrations using the ^{210}Pb dating technique to establish the time history.

In an area which may be contaminated by man's waste material, the natural background of heavy metals cannot be obtained from any measurement of contemporary samples of the water, sediment or biota. It must be determined from the samples collected at a previous date, before man's input. However, if measurements of samples are not available, an indication of the amount of heavy metals which were present at the previous date, at least in the sediments, may be obtained from the measurement of the heavy metal concentrations in accurately dated core profiles. It has been assumed that the migration of elements in the sediment profile is negligible, although this assumption may not be valid for certain elements, sediment types, and water conditions.

The use of the ^{210}Pb dating technique for 14 cores collected in central Puget Sound and the enrichment of the heavy metal concentrations in sediment layers between the time period of 1900-1920 and 1955-1975 are shown in Table 1. Since the sedimentation rates differ at various core sampling locations, the ^{210}Pb dating technique has been used to reconstruct (normalize) the average concentrations of trace metals which were deposited as sediment during the above-mentioned time periods at each station. This most significant enrichment of several heavy metals is found at station 41053, which is located 2 miles north of the West Point outfall, and at station 41051 which is located 2 miles east of the West Point outfall. At these 2 stations the particle size measurements show that the silt and clay fractions are greater than at other nearby stations; this indicates that the pollutant heavy metals are associated with fine sediment particles. The maximum enrichment (station 41053) is for Cu (2.8) and Pb (3.6); all other metals

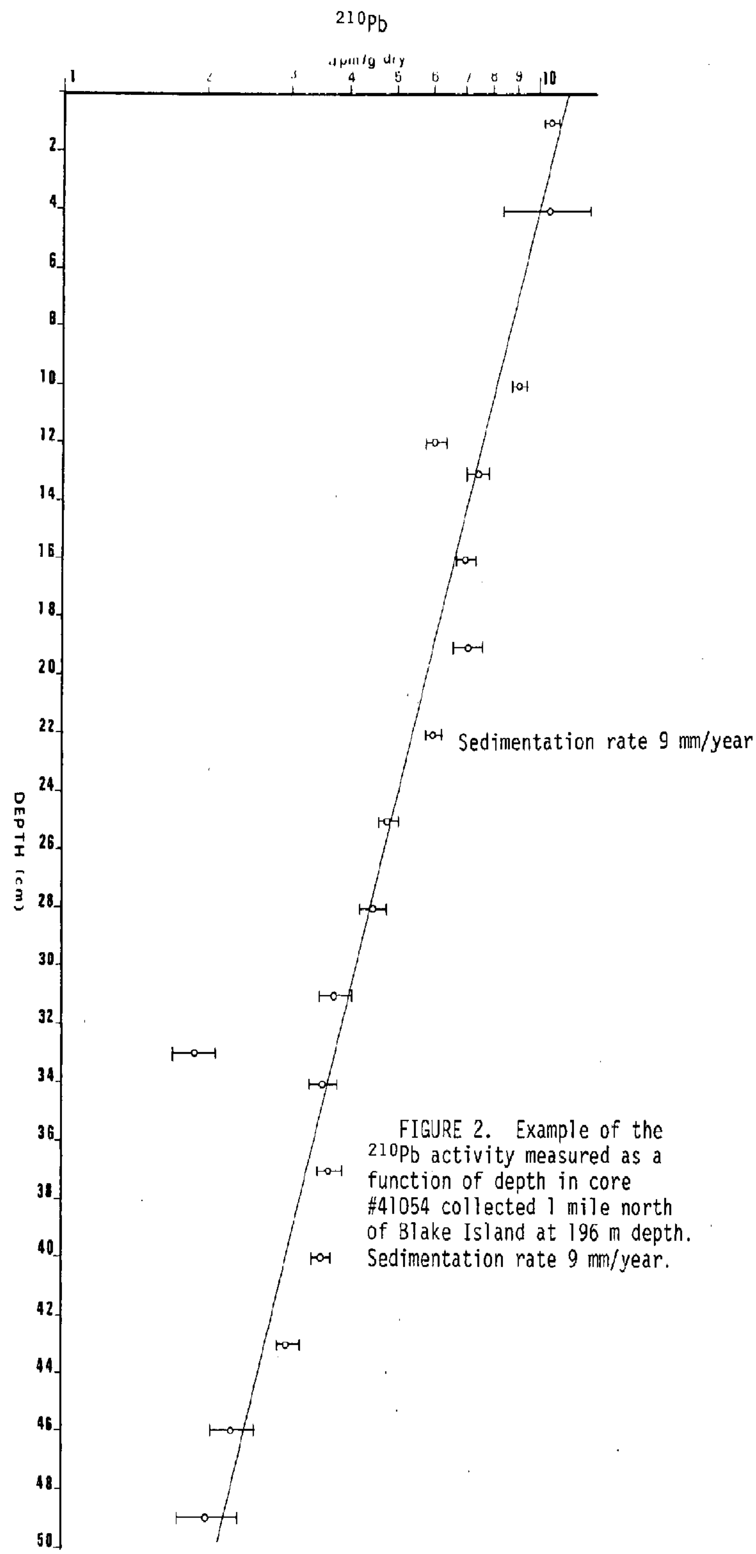

FIGURE 2. Example of the ^{210}Pb activity measured as a function of depth in core #41054 collected 1 mile north of Blake Island at 196 m depth. Sedimentation rate 9 mm/year.

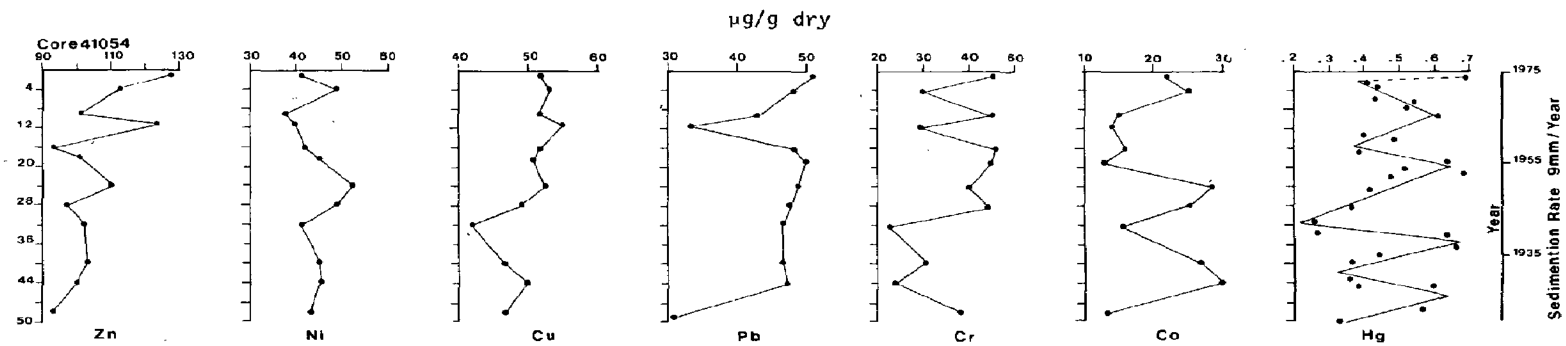

FIGURE 3. Concentration profiles of Zn, Ni, Cu, Pb, Cr, Co, and Hg in core #41054 collected in central Puget Sound. (Concentrations in µg/g, dry, ± 15% single sample analytical error.)

Table 1. Surface Sediment Enrichment of Trace Metals in Central Puget Sound. Average concentrations in 1955-1975 time periods are divided by those of the 1900-1920 period.

Area	West Point				Elliott Bay		Alki Point					Control Stations		
Core #	41293	41294	41053	41051	41062	41668	41160	41059	41058	41055	41054	41162	41157	41292
Lat. (N)	47°39'43"	47°39'54"	47°40'30"	47°38'49"	47°37'40"	47°36'50"	47°33'5"	47°33'46"	47°32'31"	47°33'35"	47°33'35"	47°44'48"	47°29'5"	47°50'48"
Long. (W)	122°28'13"	122°27'49"	122°25'44"	122°29'14"	122°24'56"	122°26'52"	122°27'5"	122°25'23"	122°24'53"	122°28'5"	122°28'5"	122°25'42"	122°30'5"	122°30'44"
Water depth (m)	246	240	100	190	175	196	250	157	187	183	196	283	102	160
Particle Size %***														
Sand	9.4	85.6	8.6	85.6	4.7	4.2	30.9	39.1	72.8	85.9	85.9	65.9	87.9	74.6
Silt	51.6	6.5	50.7	6.5	49.4	49.2	34.6	34.5	13.4	6.8	6.8	17.5	2.7	9.9
Clay	39.0	7.8	40.7	7.8	45.9	46.7	34.6	26.4	13.7	7.3	7.3	12.3	2.8	4.8
Sedimentation Rate (mm/yr)	3.4	5.0	4.5	3.9	10.3	8.1	3.7	3.9	10.2	5.9	9.0	2.0	2.2	3.1
Zn	1.1	*	1.8	1.4	1.0	1.4	1.1	1.4	1.1	1.3	1.2	*	1.0	1.6
Ni	*	1.0	1.2	*	*	1.1	*	*	1.0	1.4	1.0	*	*	1.2
Cu	1.0	1.1	2.8	1.3	*	1.5	1.0	1.7	1.0	1.3	1.1	*	1.0	1.8
Pb	1.8	1.1	3.6	1.6	1.1	1.7	*	2.2	1.2	1.9	1.5	1.8	1.0	1.8
Cr	1.0	1.0	1.2	1.2	*	1.1	1.1	*	*	1.3	1.2	1.0	**	1.4
Mn	1.1	1.0	1.3	1.2	*	1.3	**	1.0	*	1.7	1.0	**	**	1.0
Co	1.0	1.0	1.2	1.2	1	1.1	1.0	1.0	1.0	1.2	1.3	1.0	**	1.0
Hg	2.4	1.3	1.8	1.3	**	**	1.4	1.7	1.3	1.6	1.6	**	**	6.1

* *Metals depleted in top layers.*

** Not measured.

*** Reported by Roberts (19)

measured have an enrichment of less than a factor of 2. The enrichment appears to be localized to the immediate vicinity of the outfall, although the data are too limited to give better regional distributions.

Core 41054 has high concentrations of heavy metals in sediments even though it was taken at a region far from the outfall plume. The metal concentrations do not appear to have changed greatly at this station over the past 50 years (49 cm). The metal values measured in the surface section (Pb, 54 ppm; Cu, 52ppm; Zn, 122 ppm; Cr, 47 ppm) are comparable to concentrations measured in sediment cores collected near the industrial areas and population centers of Puget Sound. The area where the core was taken must be a natural sink for sediment, which may be due partly to the eddies which are formed at the north end of Blake Island (Schell et al.1976).

CONCLUSION

The results show that the effective sedimentation rates in central Puget Sound range from 2-10.3 mm/year and depend strongly on the physical circulation of the water, proximity of the land and rivers and the bottom topography. The sedimentation rates are higher than the adjacent continental shelf area (Nevissi and Schell unpubl.). The enrichment of heavy metals in sediment layers has been determined from the values obtained from layers which were over 50 years old. Enrichment of trace metals were observed only in the vicinity of West Point and Alki Point. This probably has resulted from dumping sewage or sludge from sewage treatment plants. The development of plans for the rational use of Puget Sound should include information on the sedimentation rates and residence times of water and particulate matter.

ACKNOWLEDGMENT

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SITE SELECTION AND DESIGN OF COMMUNITY OUTFALLS IN PUGET SOUND

Gary R. Minton, Jeffrey M. Rice, Grant Bailey, and Steven Fusco
URS Company

INTRODUCTION

Society can be expected to continue to use Puget Sound as a receiving water for its treated wastewater effluents. Continuation of this practice requires that careful consideration be given to the site selection and design of new community outfalls. Legal requirements, the environmental sensitivity of the public, and the desire of the environmental planner to seek a satisfactory solution require the use of a procedural methodology which results in a decision concerned parties will believe is environmentally sound.

A wastewater facilities plan for the Silverdale area recommended in 1974 to abandon the overloaded primary plant at Silverdale, which discharged into Dyes Inlet, with a new secondary treatment plant and outfall at Brownsville (Figure 1). The plan was reviewed and approved by community leaders and the public according to the regulatory procedures in effect at the time. The placement of a new outfall at Brownsville was agreed upon because of the adverse water quality conditions in Dyes Inlet.

In 1974 the Department of Defense announced its intention to construct the Trident base at Bangor, and asked Kitsap County to evaluate the feasibility of discharging the base's wastewater to the proposed Silverdale system. Apprehension by the local residents as to the potential environmental and social impact of the Trident facility resulted in reevaluation of the previously accepted wastewater facilities plan. Among other elements of the plan, they requested a reevaluation of the outfall site including the consideration of additional alternatives and a more detailed analysis of each alternative.

As Kitsap County's consultant, we advised them to begin the planning process completely anew, rather than to simply consider modifying the proposed plan. Time was of the essence because the increased population in the Silverdale area was creating a potential health hazard in Dyes Inlet and the water supply wells. It was essential to develop and implement a planning methodology which would fully satisfy the public's questions and new regulatory requirements, thereby avoiding potential delay over unresolved issues.

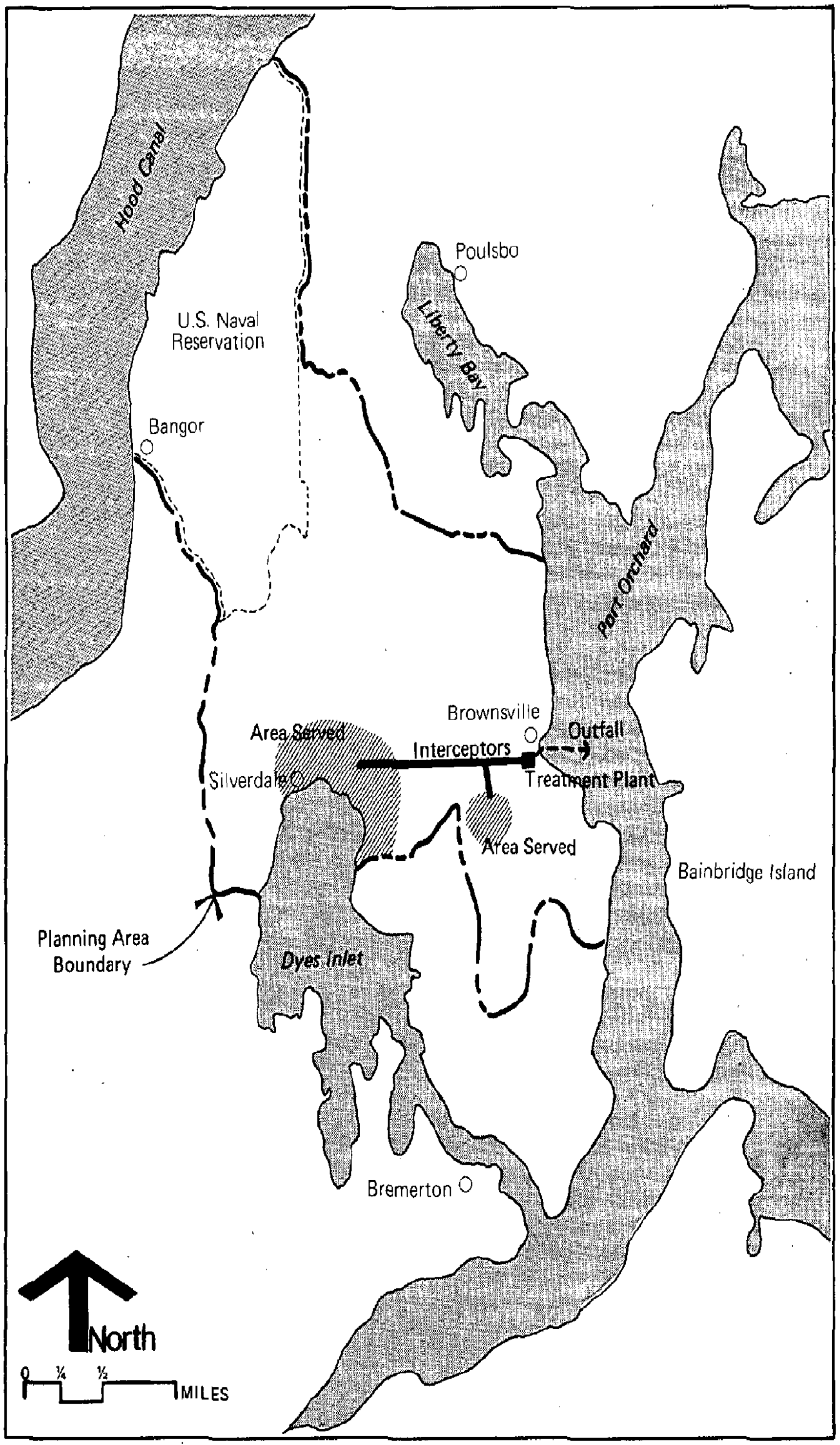

Figure 1
Originally Proposed Plan

The objective of this paper is to discuss key elements of the methodology utilized, and based upon our experience with its use, suggest how existing water quality management and research programs may be modified to provide information which will improve the planning process for site selection and design of community outfalls.

BASIC CONSIDERATIONS

To develop the methodology, the planner must give consideration to numerous factors. Although they interrelate, these factors can be placed into three conceptual categories: legal, political, and technical.

Legal Considerations

Two areas of legality must be satisfied: 1) the federal and state laws, regulations, guidelines regarding water quality and 2) national and state environmental policy acts. Specifically, these include the Federal Water Pollution Control Act Amendments of 1972 (U.S. Congress, 1972) and their related regulations (EPA, 1975) and guidelines (EPA, 1974); the Washington State water quality laws (WWPC 1971, 1973; WNPDES 1974, 1976) and standards (Washington Revised Code, 1977), and the Department of Ecology (DOE) guidelines on the definition of mixing zones for outfalls (DOE, 1973).

Washington standards (WWQS, 1973, 1977) specify conditions for various physical, chemical and biological parameters. Of particular interest to this paper are the toxic substances standards. No limiting concentrations for these substances are specified. Rather, it is stated that deleterious concentrations of toxic materials "shall be as determined by the Department (DOE) in consideration of the Report of the National Technical Advisory Committee on Water Quality Criteria, 1968, and as revised and/or other relevant informations" (WWQS 1973, 1977).

Washington regulations specify the relationship between standards and mixing zones, specifically: "except for the aesthetic values and acute biological shock conditions the water quality criteria . . . shall not apply . . .within . . .mixing zones. The total areas and/or volume of a receiving water assigned to a mixing zone shall . . . not interfere with . . . important species to a degree which is damaging to the ecosystem; nor diminish other beneficial uses disproportionately." (WWQS 1973, 1977). Guidelines (DOE, 1973; EPA, 1976a, 1976b) further elucidate the constraints on mixing zones.

An important legal element of the Federal Law has been the concept of "antidegradation." (U.S. Congress 1972). As interpreted by EPA and DOE at the initiation of the planning process, antidegradation was understood to include three basic elements. First, all existing beneficial uses must be protected. Secondly, high quality waters must be maintained at their existing quality, unless limited degradation is economically and socially justified. Finally, the wastewater is to be provided with all known, available, and reasonable methods of treatment. These concepts have recently been included in EPA guidelines (EPA, 1976b) and the presently proposed new standards for Washington (WWQS, 1973, 1977).

Attention must also be given to the State (SEPA) and Federal (NEPA) Environmental Policy Acts (U.S. Congress, 1970; WEPA, 1971)(U.S. Congress, Washington Revised Code 1971) Of special concern here are two major elements of these two Acts and their attendant guidelines and regulations (DOE 1972, 1976; EPA, 1973, 1974b). These are the public involvement requirement, and the requirement to consider all alternatives via an adequate method of comparison.

Political Considerations

In general, the public is apprehensive about the location of an outfall in their "backyard." This apprehension is complicated by an attitude, not necessarily unhealthy, of skepticism and at times a lack of understanding of basic environmental processes. The most often heard issues raised by the public are the potential harm to humans and/or aquatic life by "fertilization," heavy metals, and chlorinated hydrocarbons; land disposal in lieu of water body disposal; and the precision and accuracy of the technical tools.

Technical Considerations

Site selection and design of the outfall require the quantification of the potential impact of the discharge on water quality, the biological receptors, and other beneficial uses which exist within the vicinity of each of the alternative sites. To do so, it is necessary to outline a technical procedure at the begining of the planning process. This procedure may follow six general steps:

Select mathematical models for predicting physical dilution and changes in water quality.

Characterize physical, chemical and biological conditions of the alternative outfall sites and effluent.

Select criteria for toxic pollutants from literature.

With the above tools and information, calculate physical dilution, changes in water quality and biological impact at the alternative sites.

Select the most cost-effective site which fulfills the prescribed environmental criteria.

Design the outfall diffusor to provide the required dilution.

The description of existing conditions at the sites can occur by one or both of two methods: review of existing data and baseline studies. Conceptually, the procedure is to identify what data are required by the analytical tools identified in the first step, extract relevant data from the literature and then conduct a field program to obtain the remaining data. The characterization of the effluent follows essentially this same procedure.

PLANNING METHODOLOGY--CENTRAL KITSAP COUNTY PROJECT

The authors synthesized the above considerations into a planning methodology which was introduced to the regulatory agencies and the public in March, 1975 (URS, 1975). A preliminary draft document (Phase I) was published in July, 1975, with a public hearing held on July 25th. The completed draft plan (Phase II) was published in December 1975, with a public hearing on January 25, 1976. The final document was published in March, 1976 (URS, 1976).

Our focus on this project was to comply with legal requirements and water quality standards. Although legally required to consider "all" alternatives the number of alternatives was necessarily limited by time and funds available but was also limited in order to make the final selection process more coherent and manageable. Therefore, alternatives were selected which provided a sufficiently broad range to allow a real choice. Based on this logic, the alternative outfall sites shown in Figure 2 were selected.

The definition of an "adequate" technical approach was much more difficult. The regulations and guidelines which support SEPA and NEPA provide a succinct framework of topics which must be addressed, but provide neither an indication as to the depth to which each topic must be addressed, nor a methodology by which to determine the appropriate depth.

We were, therefore, left with exercising our subjective professional opinion as to what constitutes an adequate approach. The authors concluded that the public's perceptions, and therefore their involvement, were essential to the success of the planning process and in determining adequacy. Consequently, aside from the ethical question of involving the public as intimately as possible in the process, it was found to be very essential given the nebulous nature of "adequacy."

Several vehicles were utilized to involve the public. A Citizens Advisory Committee (CAC) was established, composed of both proponents and opponents of the original plan. The technical approach was published (URS, 1975) to provide an opportunity for the CAC, as well as the public at large, to comment on the approach before planning began. All alternatives that were to be considered were included in the document as well as the procedures for their evaluation. Frequent meetings were held with community clubs. Issues of most concern to the public were identified and addressed. A preliminary draft report was published early in the planning process, indicating the alternatives which, after a preliminary objective analysis, would be given more detailed consideration in Phase II. Thus, the public was given a formal opportunity to provide us with a mid-course correction. Finally, the completed draft plan was presented. Of the original eleven outfall site options three were recommended for consideration by the public. Based upon their comments the final site was selected.

The objective of a technical analysis is to provide the proper combination of treatment, outfall site selection and diffusor design which will avoid a violation of standards. However, within existing standards, the term "violation" could be interpreted as having found one sample or one computer prediction for which the concentration of the particular pollutant exceeds the standard value specified. However, our analytical tools, as well as the complexity of nature will not allow us to guarantee that a violation as defined above will not occur.

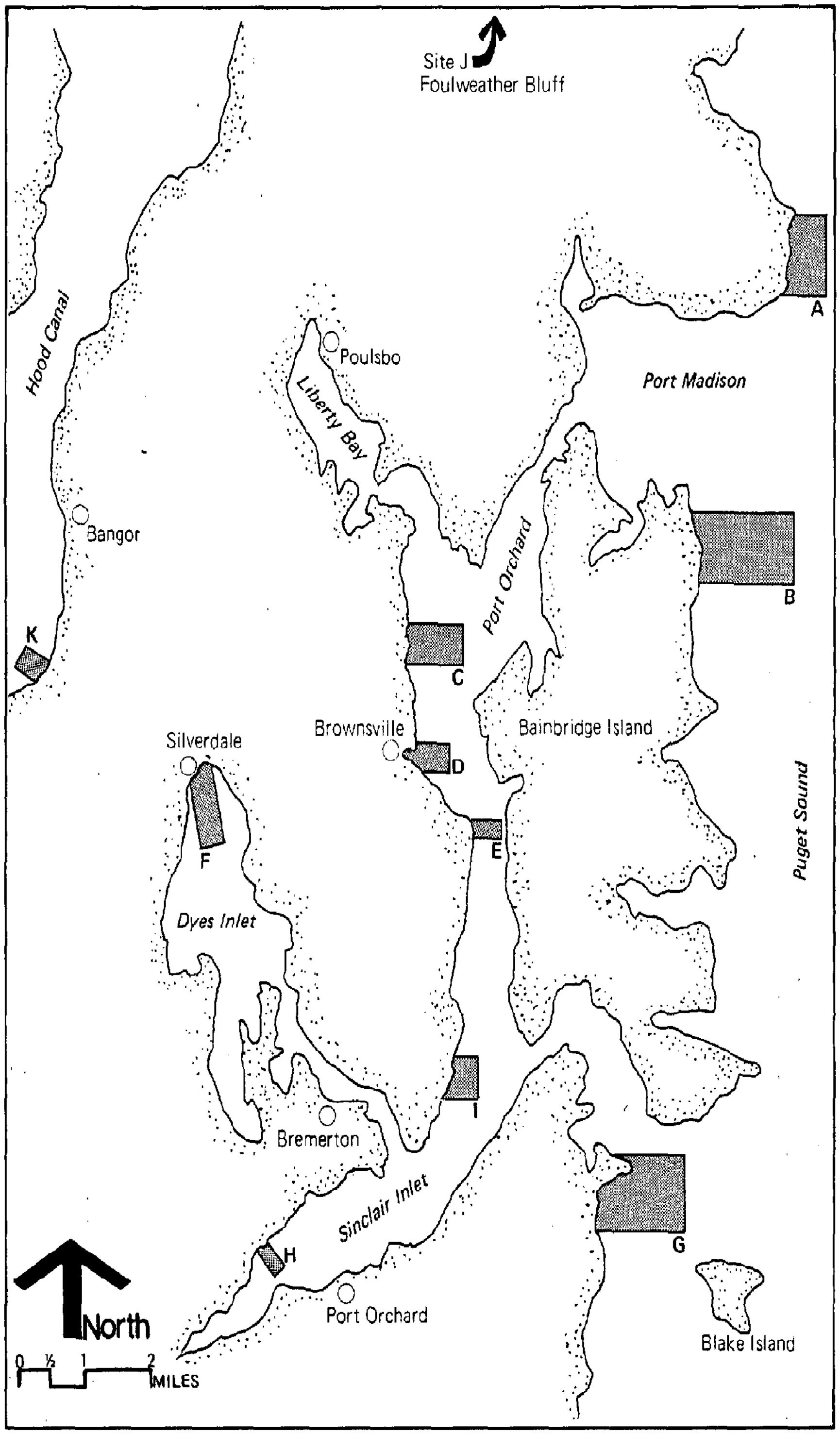

Figure 2
Alternative Outfall Sites

It became apparent early in the analysis that the most likely standard that would possibly be violated was acute toxicity in the mixing zone. The standards state that acute toxicity will be avoided but give no numerical values. We therefore had to rely on recommended criteria to derive actual values not to be exceeded (EPA, 1976; FWPCA, 1968; EPA, 1972).

It is important to realize that if the proposed criteria are used to represent the standard, present municipal discharges are in violation with regard to chlorine. Presently, chlorine residuals in municipal discharges are on the order of 1 mg/l, not 0.002 mg/l and present acceptable cannot achieve a final value of 0.002 mg/l. Short of providing very sophisticated treatment which we believed would be neither acceptable to the community nor to regulatory agencies, the authors decided to dechlorinate with the use of sulfur dioxide to achieve a residual of about 0.1 mg/l and complete the dilution within the mixing zone.

It was our belief that acute toxic conditions could possibly occur with regard to ammonia and some heavy metals. It was concluded that reduction for these two items would be accomplished by biological oxidation of ammonia to nitrate and chemical precipitation and clarification of the heavy metals, if the analysis confirmed our preliminary judgments.

The standards specify that the mixing zone will "not interfere with biological communities or populations of important species to a degree which is damaging to the ecosystem." The definition of "important species" must occur on a case by case basis, and is subject to a variation in opinion within regulatory and scientific circles. The authors' approach was to identify a sensitive species based upon a biological survey at the site and the available data on organism/toxic level relationships. The coho salmon was selected as the sensitive species.

The final important aspect of the standards is the antidegradation policy. As previously indicated, the policy consists of three elements: maintenance of existing high water quality; no compromise to existing beneficial uses; and provision of all known, available and reasonable methods of treatment.

The problem with the first element is the question of what parameters are to be considered and what constitutes a change. The authors assumed concern only for those parameters identified in the standards, but significant change remained open to the interpretor. The potential compromise to beneficial uses was avoided by not considering any sites immediately within or adjacent to significant benthic communities. Regarding the final element, provision of treatment, a "reasonable" (i.e. economical) method has typically been considered to be secondary treatment. However, this is no longer the case. Dechlorination by sulfur dioxide is financially reasonable. In addition, it is quite reasonable to provide additional capacity within an activated sludge system to oxidize the ammonia to nitrate, thereby avoiding ammonia toxicity. A reduction in heavy metals can be achieved with chemical clarification, and nutrient reduction is also quite feasible. In the eyes of the public, it is difficult to "hide behind the skirts" of secondary treatment. Thus, the authors considered all of the above options reasonable and open to cost-evaluation if water quality conditions warranted.

The technical analysis consisted of three interrelated elements:

- Physical dilution
- Water quality changes
- Biological community

A preliminary reduction to three sites from the original eleven was achieved via the use of the University of Washington's physical model of Puget Sound. A qualitative evaluation resulted in grouping of the sites into four categories: best, good, fair, and poor. The eleven sites were then placed into three geographical groups: Dyes Inlet/Hood Canal, within Port Orchard, and in Puget Sound proper. A site was then chosen within each of these groups that appeared to provide the most dilution. If two sites within each geographical category provided relatively the same dilution, the less expensive option was chosen. The three sites chosen for final consideration were Dyes Inlet (Site F), north Port Orchard (Site C) and Point Monroe (Site B). (Figure 2).

Field investigations were then conducted at the above three sites to confirm the prediction of the physical model, provide water quality data and hydraulic information for far and near field prediction models, and provide the biological characterization.

The mathematical models available for predicting near and far field dilution and incremental changes in water quality are reasonably well developed. However, uncertainty remains as to the level of effort, in particular the amount of field work, which must be expended in identifying the values for the input parameters, and verifying with field experiments the results predicted by the models. Uncertainty also exists as to how the biological portion of the field program should be structured both spatially and temporally to provide a satisfactory description of the alternative sites.

Both of the above points have a direct bearing on the intensity of the field program, which in turn affects cost and schedule. The basic question the planner must ask him/herself when developing the field program is "How much will the additional data improve the decision?" S/he must ask this question not only from the technical perspective but also from a political one. It must be determined whether, upon final analysis, the public will be convinced that the decision was based upon an adequate data base. While minimizing the data collection phase will save time and dollars the value must be weighed against the possibility of project delay from public questioning of the validity of the data base used.

For this project, all biological sampling occurred during a 2-week period in August. Hydraulic monitoring (i.e. to calculate the total mass balance movement into and out of Port Orchard) occurred over a 4-month period from May to September. Water quality sampling occurred every 3 weeks during the same time period. Intensive drogue and water quality sampling periods occurred twice over a 39-hour period: once in July and once in August. The 39-hour sampling periods included vertical measurements of water quality. Current and quality measurements occurred at the surface and at several depths, some down to 40 meters.

Far field water quality changes were predicted using the EPA mathematical model of Puget Sound. Near field predictions of dilution were made using the methods of Baumgartner (Baumgartner et al. 1971) Brooks (1959), and Chao (1975).

A literature review provided criteria upon which to judge the question of toxicity. Analyses of the effluent presently discharged at Silverdale provided some indication of heavy metals and ammonia concentrations. This information was then compared to the biological organisms observed at the site. The comparison of wastewater characterization data to the literature review on toxic criteria indicated chlorine, ammonia, and possibly copper were of most concern. The sensitive organism was considered to be the coho salmon. The conclusion of the toxicity analysis was the dechlorination should be provided, as well as oxidation of ammonia to nitrate.

Far field water quality predictions indicated possible violations of dissolved oxygen in Dyes Inlet with possible problems of nutrient fertilization. No noticeably adverse impacts were predicted at the other two sites. Near field predictions of dilution indicated that good dilution could be achieved within reasonably sized mixing zones at all three sites. Based upon the overall analysis, the north Port Orchard site was chosen, with the treatment process including dechlorination with sulfur dioxide and biological oxidation of ammonia.

Further hydraulic, meteorological and water quality field work was conducted in September and December of 1976 at the north Port Orchard site to provide a more definitive evaluation of the horizontal and vertical hydraulic characteristics of the site. The data were used to determine numbers of ports and their sizes, the diffusor pipe diameter, and the diffusor's placement in relationship to the currents.

RECOMMENDATIONS

The first recommendation is for regulatory agencies and local governments to recognize the sensitivity of the public to site selection for a new outfall. Failure to do so may result in unnecessary delays of a project, as occurred for the Central Kitsap County facility. A delay of approximately 2 years resulted in an increase in the project cost of about $1,600,000, or about 14% of the originally estimated cost. Given this realization, it is more likely that sufficient funds would be provided to a planning process and result in a decision which is more readily acceptable to the public.

Within the planning process itself, it is recommended that an aggressive, open approach to public involvement be pursued, seeking a wide range of opinions from citizens. A particularly valuable tool is to publish, prior to the commencement of the planning process, a work plan which describes in lay terms the nature of the project, the alternatives that will be considered, the structure of the field studies, and the technical approach by which the alternatives will be compared. Based upon comments by both the public and relevant agencies, the work plan can be modified. This will minimize the opportunity for criticism of the planner's methodology at the end of the planning process. The publishing of interim outputs, allowing public input on decisions made during the planning process, is also highly recommended.

DOE can improve the situation by a reevaluation of some aspects of its regulations and guidelines. With regard to the water quality standards, DOE should give careful consideration to four areas. First, a specific definition of what constitutes a violation should be made, based upon frequency of values exceeding the standard over a given time period and with due consideration to the number of samples which must be taken with regard to the uncertainty of field sampling and laboratory analysis. Secondly, specific numerical values should be established for potentially toxic substances. Obviously, this cannot occur for all toxicants, but the state-of-the art should allow it for heavy metals, chlorine and many synthetic hydrocarbons. Third, the "sensitive species" should be identified. Finally, to conform with the realities of existing treatment technology, the present definition of mixing zone should be modified to state that the standards do not apply to acute biological shock within the mixing zone for marine outfalls.

DOE should also provide more guidance as to site evaluation for outfalls and what constitutes adequate procedure for site comparison and diffusor design. Certainly, there exist areas where outfalls will not be allowed regardless of the level of treatment given the location of sensitive biological receptors, the existence of hydraulic nodal points, and water based recreation. These should be identified. Also, guidelines for site comparison and diffusor design should identify the basic structure of the analytical evaluation, including minimum data requirements to represent critical tidal, seasonal, and meteorological periods. The guidelines should have sufficient flexibility to allow a variation in the intensity of the evaluation as determined by the variation in hydraulic conditions within Puget Sound and the volume of discharge in each case.

It is recognized that DOE cannot, given the state-of-the art and differing opinions of the scientific community, arrive at a satisfactory conclusion for all of the above items during its first attempt. At a minimum, some modifications of regulatory policy within the above four topics will be accomplished, and the exercise will indicate what areas of applied research require modification and/or enhancement to provide the kind of information needed to complete the above process.

Our experience has also provided us with suggestions for existing research programs. We suggest that the investigators, when drawing conclusions from their data, attempt to relate those conclusions to present standards whenever possible. It is also recommended that the scientific community support DOE by synthesizing existing knowledge of Puget Sound to answer these questions: what is the fate of toxicants discharged to Puget Sound; what is the impact--specifically what do we know about the LC_{50} values for various toxicants; what are the "sensitive" species? This exercise again will tell us what we do and do not know in specific relationship to regulatory standards. The scientific community should also address issues raised by the public on chlorine, chlorinated hydrocarbons, metals, and land disposal--specifically, what do we know and how valid are these issues?

Our final recommendation is that a formal forum be established with representatives of the regulatory agencies, local governments, organized environmental groups, industrial research scientists and the consulting profession participating. The forum would hold workshops at regular intervals. Data and knowledge gathered since the previous workshop would be synthesized and related to the basic management questions originally agreed upon to ascertain the progress of our management program and our understanding of what is occurring in Puget Sound. Based upon the findings of each workshop, recommendations could be made as to how both the environmental criteria by which we manage the quality of Puget Sound, as well as the structure of the research programs by which we gain knowledge to reevaluate those criteria, should be modified. Only if such an assertive approach is taken will we make real progress in achieving the goal established by this symposium.

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POLYCHLORINATED BIPHENYLS (PCB's) IN PUGET SOUND:
PHYSICAL/CHEMICAL ASPECTS AND BIOLOGICAL CONSEQUENCES

Spyros P. Pavlou*, R.N. Dexter* and W. Hom
University of Washington

INTRODUCTION

The importance of organic compounds in controlling the biological, chemical and geochemical processes in marine systems is well recognized. However, the continuous increase in consumer and agricultural products on a global scale, has precipitated a serious concern regarding the accelerated buildup of organic compounds in the biosphere and the potential change of ecosystems (Neuhold and Ruggerio, 1977; Blodgett, et al., 1975). Since the marine environment provides a natural sink for these chemicals, understanding their transport, their interactions with the various components of the ecosystem and their ultimate degradation and removal are crucial factors in predicting their accumulation and toxicity potential to the biota.

The polychlorinated biphenyls ($C_{12}Cl_NH_{10-N}$ with N = 1, 2 . . . . 10) are well recognized as ubiquitous components in aquatic ecosystems (National Academy of Sciences, 1971; Nelson, 1972; Lee and Falk, 1972). Their worldwide occurrence has become an issue of increasing concern due to their continued global production and persistence, their slow rates of chemical and biological degradation, their capacity for bioaccumulation, and their toxicity to living systems.

Coastal ecosystems in particular receive substantial input loads of chlorobiphenyls (CB) with the main sources being industrial and municipal sewage outfalls, river runoff, aerial fallout, and dredge spoil disposal (Nelson, 1972; Schmidt, et al., 1971; Holden, 1970; Bidleman and Olney, 1974). Since these regions are capable of providing large quantities of harvestable food resources, as a result of high productivity in the lower trophic levels (Ryther, 1969), any biological effects induced by CBs are of critical importance to man and the stability of the ecosystem. Furthermore, these compounds have been shown to alter the species composition of mixed phytoplankton cultures (Mosser, et al., 1972; Fisher et al., 1974). Consequently, adequate information on current residue quantities and distributions in lower pelagic trophic levels is essential for predicting potential effects at the ecosystem level.

*Present address:
URS Company, Fourth & Vine Bldg., Seattle, WA 98121

In 1972 we initiated a project to study the distribution of CBs in Puget Sound. The project included a baseline assessment of CB levels in the major subregions of the estuary and laboratory investigations to evaluate their accumulation in marine phytoplankton and their toxicological impact to algal growth. These studies were intended to provide a data base for adopting appropriate criteria for regional enforcement, as well as an estimate of the potential hazard to the ecosystem in terms of their effect on the primary productivity of the region and the associated long term implications to ecosystem dysfunction. However, throughout the course of the study it was realized that in order to assess the impact of these chemicals on the lower trophic level biota, it was necessary to obtain some quantitative information on the mechanism of accumlation based primarly on field residue data which reflect the actual concentration levels commonly encountered in the marine environment. Therefore, during 1973 and 1974, the emphasis in research was shifted from the biological aspects to chemical considerations. The main concern was to assess the distribution and bioaccumulation characteristics of CBs in terms of the physical chemical processes that control their flow throughout Puget Sound. From 1975 to 1976, enough CB residue data were acquired to initiate interpretive procedures. Since 1976, we have been developing both theoretical and empirical models to validate the field results. For the low levels detected in seawater, the data suggest that accumulation in the various marine components, including biological uptake, is predominantly governed by equilibrium partitioning of the chemicals between suspended phases and ambient water. Therefore, the concept of equilibrium partitioning has been the fundamental framework upon which both the analysis of the data and formulation of the recommendations for regulatory control have been based.

The material presented in the paper includes; 1) a general discussion on the characteristics of the CB distribution in Puget Sound, 2) an evaluation of their partitioning in suspended phases and lower level biota, and 3) a set of criteria recommendations applicable to the region.

DISTRIBUTION OF CHLOROBIPHENYLS IN PUGET SOUND

The field program completed during these studies has provided us with a sufficient data base to obtain a fairly coherent and comprehensive description of the distribution of CBs in Puget Sound. A complete presentation of the CB data together with supporting hydrographic and biological measurements is available elsewhere (Pavlou, et al., 1973; Krogslund, 1975; Pavlou, et al., 1977); these publications also contain a detailed discussion on sampling and analytical methodology. Two additional projects have also added substantial supporting information to our data base.

One of the projects, Duwamish River Dredge Project (DRDP), was conducted under support from the U.S. Environmental Protection Agency, through the Region X Laboratory. The sampling scheme was designed and conducted to monitor the release of polycholorinated biphenyls (PCB) during the dredging operation of Slip-1 in the Duwamish River and was part of the overall cleanup monitoring program conducted by the Region X Laboratory. The results from this investigation have been published elsewhere (Pavlou, et al, 1976; Hafferty, et al., 1977). The second project, Elliott Bay Disposal Project (EBDP), to be completed by July 31, 1977, involves the evaluation of PCB pulses induced by the dumping of contaminated sediments in Elliott Bay in an effort to establish criteria for open water dredge disposal operations. This study is part of a multifaceted physical, chemical, and biological program sponsored by the Corp of Engineers Dredge Material Research Program.

Characteristics of the Spatial Distributions of CB

A summary of the mean CB levels in Puget Sound is presented in Table 1. For some areas the averaging of values tends to obscure gradients which existed within the region, but they still provide a convenient basis for comparison.

Identification of Input Sources. In general, the values for all sample types correlate well with areas of increased industrial and municipal activity. The water, SPM, and sediment from the highly industrialized Duwamish River Estuary contained the highest concentrations of CB observed in Puget Sound, while undeveloped areas of the main basin, Southern Sound, and Hood Canal exhibit generally low levels in all samples. Certain local areas such as the inner harbor at Everett and Sinclair Inlet had elevated concentrations; it is interesting to note that the residue levels in zooplankton collected in Sinclair Inlet were the highest observed during the baseline study (no zooplankton samples could be collected in the Duwamish River). Although regional "hot spots" are apparent, the isolation of point sources in these areas was beyond the scope of this work.

Correlation with Circulation. In most of the regions where residues were measured, significant horizontal or vertical gradients of CBs within the water column were generally absent. These trends are illustrated in Table 2; the regional mean concentrations of CBs in whole water are given for 2 depth ranges; surface to 25 meters, and below 25 meters. This uniformity apparently extends even beyond the Sound itself, and well within some distance from Admiralty Inlet into the Straits of Juan de Fuca. These uniform, relatively low concentrations are expected in view of the rapid mixing in Puget Sound generated by tidal action, and therefore can be considered as representative of the long-term "background" concentration ubiquitous to the region. In contrast, the levels in the Elliott Bay-Duwamish River system showed distinct horizontal and vertical gradients which correlated well with the distribution of the more highly contaminated brackish layer of the river. Typical plots of CB concentrations in water as a function of salinity for a number of subsurface water samples collected in the Duwamish River and Elliott Bay are depicted in Figure 1. The concentrations of the CB decrease linearly with increasing salinity reflecting the mixing of the less saline, but more contaminated, river water with that of the bay. This is nicely demonstrated by the distribution of CB residues in the surface sediments of Elliott Bay (Figure 2). A strong gradient, with CB levels decreasing away from the mouth of the Duwamish River is evident.

Below a relatively narrow surface mixed layer, the concentrations of CBs in Elliott Bay rapidly decreased to the "background" values (Table 2). A plot of all the concentrations of CBs in whole water versus depth for all regions sampled in Puget Sound is shown in Figure 3, relatively uniform levels exist in all regions below 25 meters. The upper layer values, however, encompass a much wider range of concentrations, in part due to the data obtained in the Duwamish River. Similar behavior was observed during the DRDP and EBDP cruise series. The former

TABLE 1. Mean Total Chlorobiphenyl Concentrations in Various Regions of Puget Sound[a]

REGION		SAMPLE TYPE				
Code No.	Area	WATER [ngl^{-1}]	SPM [ngg^{-1}]	ZOOPLANKTON [$\mu g(g\text{-lipid})^{-1}$]	SEDIMENT [ngg^{-1}]	SURFACE FILM [ngl^{-1}]
9	Duwamish River	41.02 ± 12.87(4)	1019 ± 541(20)			115.5 ± 101.2
0	Elliott Bay	11.04 ± 12.50(18)	251.7 ± 198.0(27)	6.79 ± 3.13(11)	636.6 ± 828.4(4)	98.17 ± 82.82
4	Main Basin	4.33(1)	104.4 ± 31.0(3)	5.92 ± 4.40(4)		12.17(1)
5	Sinclair Inlet		167.5 ± 21.2(4)	16.17 ± 6.64(3)		
6	Whidbey Basin	4.44 ± 2.21(15)	82.14 ± 36.65(7)	3.71 ± 1.12(12)	30.15 ± 13.80(5)	
3	Northern Sound and Straits of J.F.	3.73 ± 1.72(9)		1.34 ± 1.16(3)	16.17 ± 13.52(3)	
1	Southern Sound				7.98 ± 8.27(6)	
2	Commencement Bay				28.01 ± 17.13(8)	
7	Hood Canal	2.96 ± 2.21	88.33 ± 36.68(3)	1.78 ± 0.99(4)	11.94 ± 3.03(3)	

[a] Values in parenthesis are the number of data points.

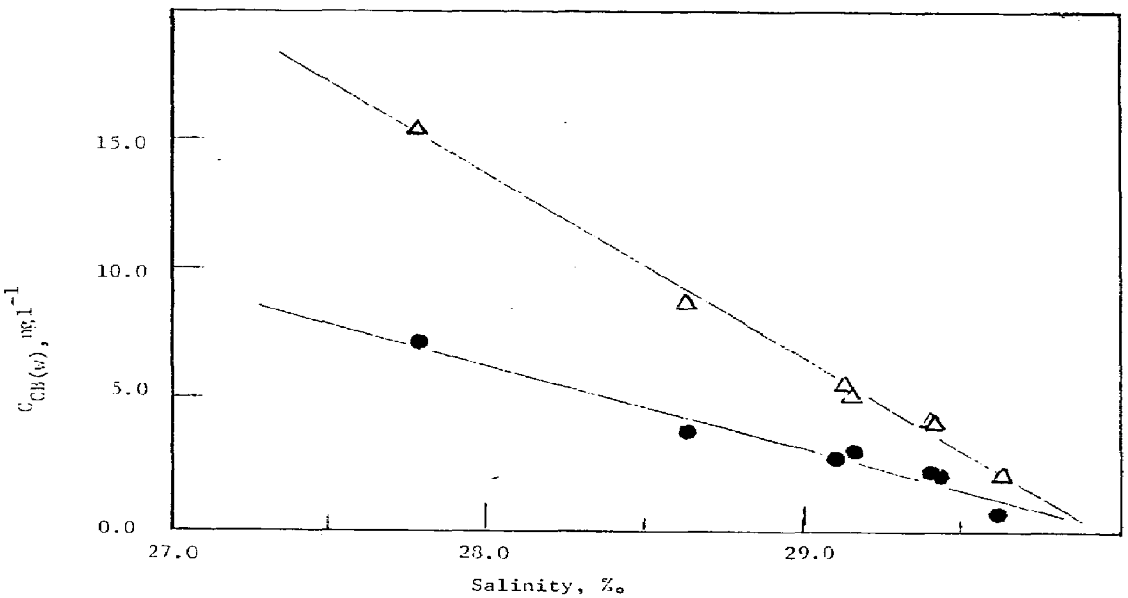

Figure 1. Plots of the concentrations of CB in water vs salinity. Δ, 5-chlorobiphenyl; ●, 3-chlorobiphenyl. The solid lines are the least square regressions.

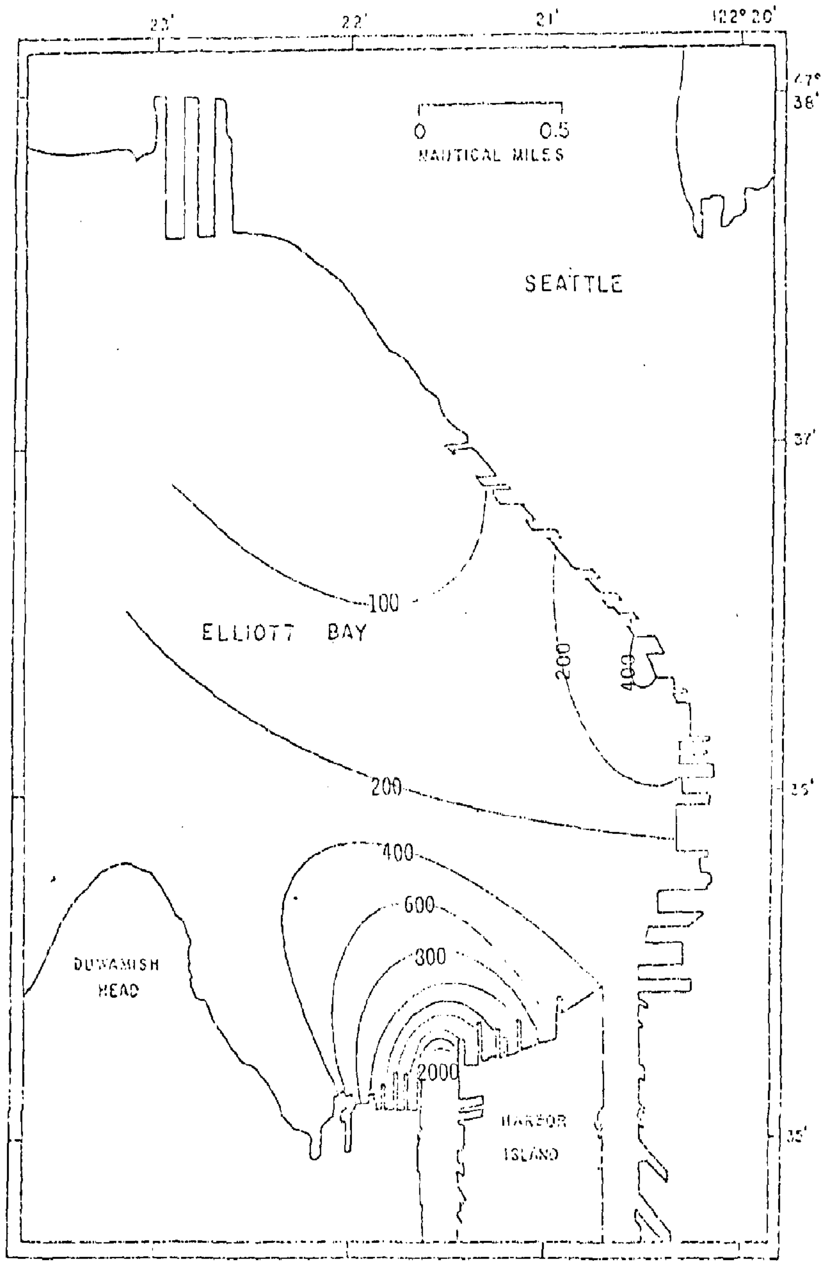

Figure 2. Contour chart of the concentrations of total chlorobiphenyl concentrations in the surface sediments of Elliott Bay. Limits are in $10^{-9}\ gg^{-1}$.

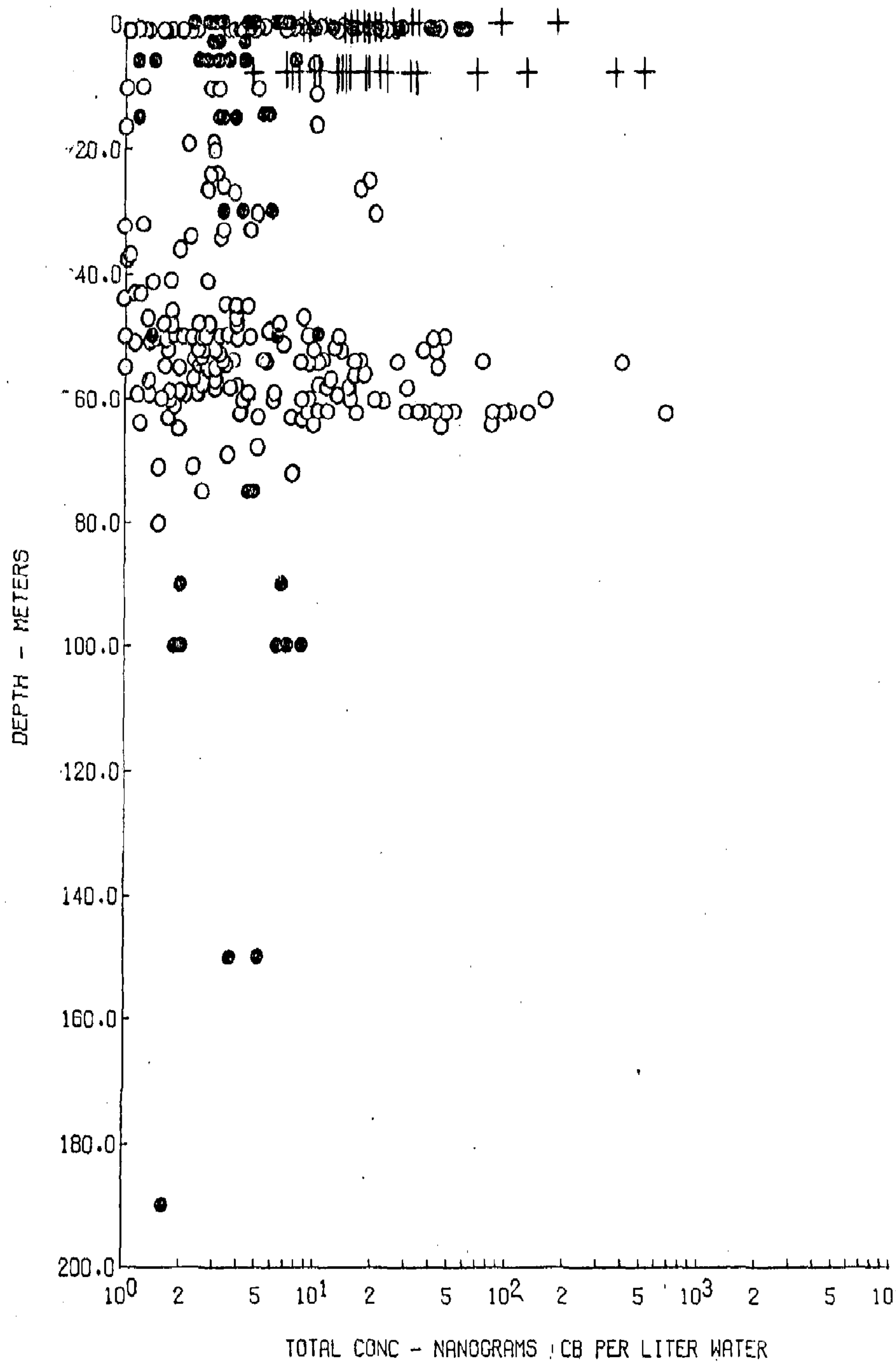

Figure 3. Plots of the concentrations of total CB in whole water vs depth for all regions sampled. SYOPS series, •; DRDP project, +; EBDP project, o.

TABLE 2. *Mean Chlorobiphenyl Concentration in the Surface and Deep Water Layers of Puget Sound*[a]

REGION		CONCENTRATION ($ng l^{-1}$)	
Code No.	Area	Surface (<25m)	Deep (>25m)
9	Duwamish River		
	SYOPS	41.02 ± 12.87(4)	
	DRDP	20.89 ± 14.35(56)	
0	Elliott Bay		
	SYOPS	13.84 ± 14.60(12)	5.46 ± 2.5(6)
	EBDP	6.96 ± 9.40(103)	27.82 ± 165 (205)
4	Main Basin	4.33	
5	Sinclair Inlet		
6	Whidbey Basin	4.15 ± 1.66(10)	5.02 ± 3.21(5)
3	Northern Sound and Straits of J.F.	3.55 ± 1.53(6)	4.07 ± 2.38(3)
1	Southern Sound		
2	Commencement Bay		
7	Hood Canal	2.61 ± 2.29(8)	3.65 ± 2.18(4)

[a] Values in parenthesis are the number of data points.

includes only Duwamish River samples, which agree with those obtained exclusively in Elliott Bay, but the vertical trends are not as obvious since most of the high values in the deep samples represent a transient pulse induced by the dumping.

Intercomparisons with Other Regions. The mean CB levels in water and sediments observed in Puget Sound are given in Table 3 together with values reported in other national ecosystems, both fresh water and marine. In general, the levels in Puget Sound are comparable to those of other contaminated areas in the nation. It is also interesting to note that concentrations of nearly the same magnitude have been detected in major oceanic systems.

Temporal Trends

While time constraints and limited equipment precluded rigorous replication in most areas, a time series profile of the CB concentrations over a 4-year period was obtained in Elliott Bay. Plots of mean CB values versus time for whole water, suspended particulate matter, sediments and zooplankton are shown in Figure 4. Within the uncertainty of the data there is no indication that concentrations in this region have changed significantly. It appears that the persistence of these compounds is due to a relatively stable diffuse input source which does not seem to have diminished despite regulatory attempts to restrict their discharge in the area. However, it should be noted that the high load of CBs in the sediments of the Duwamish River and the exchange with the water may mask any CB reduction in the overlying water that might result by a decrease in the present inputs. Very little is known about sediment-water transfer rates, but it is interesting that no long-term increase was detected in either the river or the bay following the PCB spill at Slip-1 in September, 1974.

Fluxes of CB in Puget Sound

Although the data presented below are based on gross calculations, we feel that enough information can be drawn from a variety of sources to attempt to account for the major routes of transfer of the CBs through Puget Sound. These computations are useful for identifying major sources and sinks, some of which might be subjected to regulatory control.

Input Rates. The predominant input sources which can be documented are associated with river runoff and municipal outfalls. The concentrations of CB in the atmosphere of the region are low (D. Schuetzle, personal communication) so that direct input from dry fallout and precipitation is probably negligible. However, the occurrence of transient direct inputs associated with commercial activity on the Sound has not been evaluated and should not be ruled out.

The estimated input rates are presented in Table 4. Somewhat surprisingly, the Whidbey Basin rivers appear to constitute by far the largest input source. The watersheds of these rivers are relatively undeveloped; however, they do provide nearly 75% of the fresh water input to the Sound (Friebertshauser and Duxbury, 1972). Both the Duwamish and Puyallup Rivers undoubtedly have higher concentrations of CB, but their lower fresh water flow rates reduce their contribution to the total budget. The outfalls and combined sewer overflows (CSOF) constitute relatively intense sources (approaching 300 ppt), even though not all CSOF input

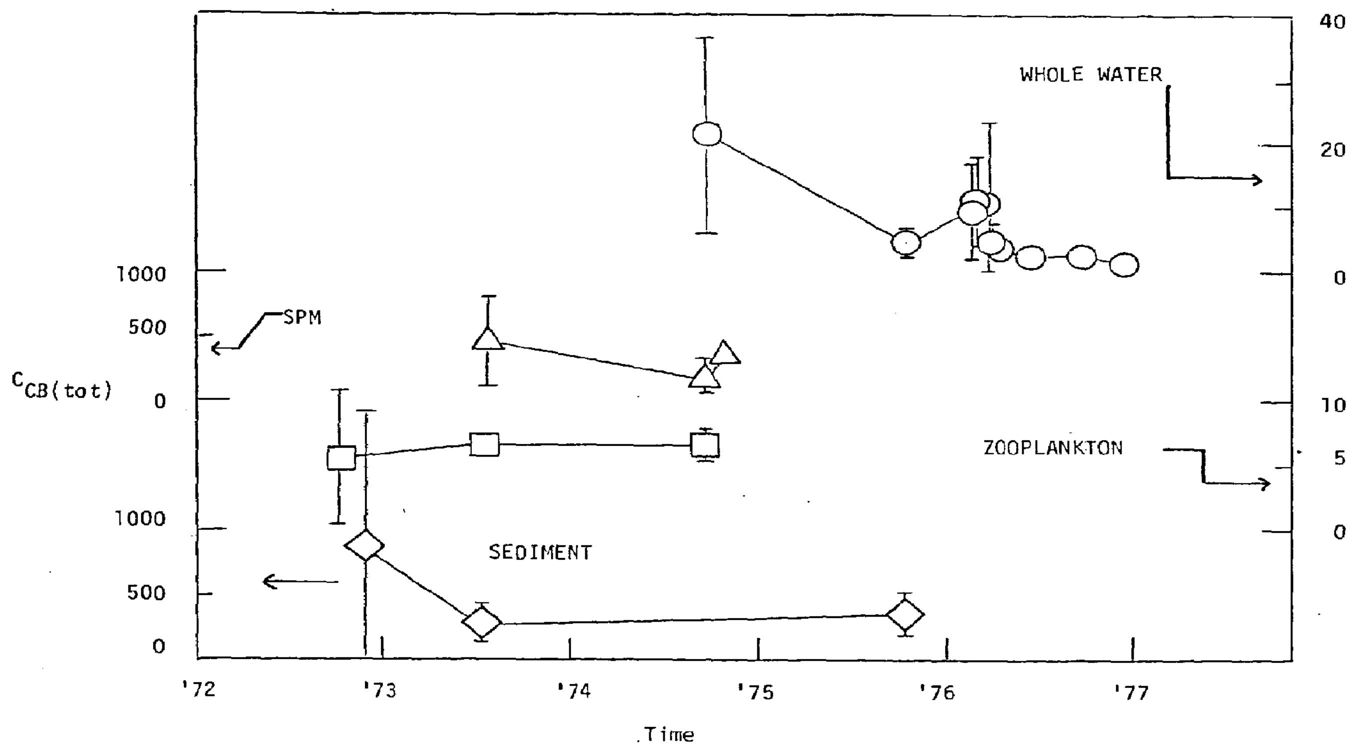

Figure 4. Time plots of the mean total chlorobiphenyl concentrations in various marine components of Elliott Bay. Whole water (ngc^{-1}), o; SPM (nng^{-1}), Δ; Zooplankton [$\mu g(g\text{-lipid})^{-1}$], □; Sediment ($nng^{-1}$), ◇.

TABLE 3. Summary of Mean Chlorobiphenyl Residues in Water and Sediments (National Levels)

REGION	WATER (ngl^{-1})	SEDIMENTS (ngg^{-1})	REFERENCE
FRESH WATER			
Lake Ontario	55	121	Haile, et al., 1975
Lake Michigan		38	Nisbet, 1977
Hudson River	$<100-2.8x10^6$	TR-6700	Nisbet, 1977
Connecticut River		TR-3500	Nisbet, 1977
Duwamish River	30	TR-2000	Pavlou, et al., 1977
MARINE			
Atlantic Ocean	<0.9-3.6		Bidleman and Olney, 1974
Gulf of Mexico	0.8-4.1	<0.2-35.0	Giam, et al. (Nisbet, 1977)
Escambia Bay	<100	190-61000	Nisbet, 1977
California			
California Current	4.4		Pavlou, et al., 1975
S. California Bight	7.4		Scura and McClure, 1975
Palos Verdes Peninsula	8.8	30-7900	Pavlou, et al., 1975
San Francisco Bay		TR-1400	Nisbet, 1977
Puget Sound	6.7	143	Pavlou, et al., 1977

TABLE 4. ESTIMATED INPUTS OF CBs IN PUGET SOUND

SOURCE	$RATE_{IN}$ ($g\ CB\ day^{-1}$)
MAJOR RIVER SYSTEMS	
Snohomish, Skagit Stillaguamish Rivers[a]	220
Lake Washington (Ship Canal)[b]	10
Duwamish River[c]	97
Puyallup River	30
OUTFALLS	
Westpoint[d]	30
Renton[d]	3
CSO[e]	10
TOTAL	400 (1.44×10^5 g/y)

[a]Based on an ambient surface water value of 4 ppt in Whidbey Basin, a total volume of the mixed layer of $19.05 \times 10^9\ m^3$ and an annual fresh water runoff volume of $2.02 \times 10^9\ m^3$.

[b]Based on a fresh water input of approximately $4 \times 10^6\ m^3$/day and an ambient PCB level in Lake Washington of 2.5 ppt.

[c]Hafferty, et al., 1977

[d]Dalseg, personal communicaltion from METRO data, 1976.

[e]Based on an ambient PCB concentration of 400 ppt, a CSO flow of $9.5 \times 10^6\ m^3$/year, Tomlinson, et al., 1976; Metropolitan Engineers, 1976.

has been accounted for in the computations (Dalseg, personal communication; Tomlinson, et al., 1976). However, these sources also have relatively low water discharge rates.

Loss Rates. The predominant losses of CB from the water column can be accounted for by advection and sedimentation. The loss rates associated with each process are summarized in Table 5. Advective losses occur primarily as the excess fresh water of riverine origin is transported out of the Sound through Admiralty Inlet. Water transport through Admirality Inlet is both into and out of the Sound. Lower salinity water generated by the entrainment and mixing of fresh and salt water within the Sound is transported out at the surface, while more saline water enters at depth. The net exchange is out of the Sound in a volume equal to the fresh water (riverine) influx. Since the concentrations of CB are comparable in the saline waters on both sides of the Inlet, no net transport of CB appears to be associated iwth the salt water exchange. Therefore the net volume out carries most of the CB quantities.

Sedimentation rates are difficult to estimate and are highly variable within the Sound; we used a mean value of 0.27 cm/yr as a rough estimate (W. Schell, personal communication). At this rate, the accumulation in the sediments is estimated to be slighly larger than the advective loss rate. However, due to the high uncertainity in the sedimentation rate value the difference might only be an artifact of the computations.

Conclusions. Even though the estimated loss rate for CBs is nearly twice that of the inputs, realistically the balance is quite good considering the gross approximations and averaging required in at least an order of magnitude lower than the corresponding SPM values. As a result, F for zooplankton is usually small, for these studies it never exceeded 4%. For the upper trophic level biota one can use the same argument, i.e., these systems will exhibit even a lower F value considering that there is a reduction of biomass in each succeeding trophic level (normally up to an order of magnitude; Riley and Skirrow, 1965), but with no commensurate increase in the K values. These observations have some important connotations regarding 1) the way the CBs and other similar organic compounds fractionate between water and suspended phases and between water and sediments, and 2) the validity of assuming a constant K.

For the first case, since the normal range for the suspended load encountered in coastal zones is within 0.5 to 10 gm^{-3} (Armstrong, 1965; Krank, 1973), compounds with $K \leq 1 \times 10^5$ will reside primarily in the water and not on suspended phases of less than 40% of the total CB load in water. Therefore, the spatial distribution of these chemicals will depend mainly on the hydrodynamics of the water column. Regarding their partitioning between water and sediments, the data support the following argument.

The dry mass of natural sediments is normally about 50% ($\approx 5 \times 10^5$ g/m^3) of their wet weight at the water interface. As a result, a relatively large fraction of organic compounds, such as both sets of calculations. Therefore, the data are sufficient to warrant the following conclusions:

1) Municipal marine outfalls probably do not constitute the major input of CB in the Sound. Although other municipalities maintain direct discharges, these are small relative to metropolitan Seattle.

TABLE 5. ESTIMATED LOSSES OF CBs IN PUGET SOUND

SINK	$RATE_{OUT}$ g-CB (g day^{-1})
ADVECTION[a] (Fresh water out only)	300
SEDIMENTATION[b]	430
TOTAL	730 (2.6×10^5 g/yr)

[a]Based on fresh water inflow and the ambient concentration of CB in Admiralty Inlet (3 ppt).

[b]Based on a mean sedimentation rate value of 0.27 cm y^{-1} (W.R. Schell, personal communication).

2) Indirect inputs, associated with industrial activity within the major river watersheds, account for the predominant input load. Whether these are industrial effluents discharging into the rivers or the results of transient inputs (e.g., spills, dumping of waste materials, residual chronic input, etc) is unknown.

3) While significant quantities of CB are continually advected out, it appears likely that the majority of the residues are retained in the sediments within the Sound. However, at present, it is not known whether sedimentation constitutes a permanent loss to the system or merely temporary storage. Undoubtedly, when contaminated sediments are disturbed, e.g., during dredging operations, at least a portion of the load is redistributed and the sediments may revert from a trap to a source. These aspects are currently being investigated under the EBDP project sponsored by the Corp of Engineers.

4) The estimated total load of CB residues presently in Puget Sound is summarized in Table 6. The data indicate that approximately 80% of the residues reside in the sediments and that the CB contamination of Puget Sound is not negligible.

PARTITIONING OF CBs IN VARIOUS MARINE COMPONENTS

When an organic molecule is introduced into a natural water reservoir, it interacts with the abiotic and biotic components of the system. These interactions include processes that take place at the boundaries between the various components and the chemical. Therefore, interfacial processes can be considered as the predominant factor that governs the flow of an organic compound through the ecosystem. Since the physical, chemical and biological interactions occurring at interfaces mediate the ability of ecosystems to absorb the chemical and simultaneously control its biological availability, the isolation of measurable paramenters and their utilization as indices of transport access component boundaries are essential to constructing explicit mathematical models for predicting the eventual environmental distribution.

These interactions can be conceptualized in the following scheme.

$$Y_i \overset{I_{ij}}{\rightleftarrows} [YI]_{ij} \overset{I_{ij}}{\rightleftarrows} Y_j \qquad (1)$$

$$Y_i \rightleftarrows \sum_n Z_{n,i} \qquad (2)$$

$$Y_j \rightleftarrows \sum_n Z_{n,j} \qquad (3)$$

$$YI \rightleftarrows [\sum_n Q_n I]_{ij} \qquad (4)$$

TABLE 6. TOTAL CB LOAD IN PUGET SOUND

COMPONENT		AMOUNT (g)
Whole Water[a]		0.34×10^6
Sediments[b]		1.33×10^6
	TOTAL	1.67×10^6

[a]Based on a value of 1.7×10^{17} g for the total mass of Puget Sound water and an ambient concentration of 2 ppt for CBs.

[b]Based on a mean value of 50×10^{-9}g g^{-1} for CBs on the upper 2 cm layer.

Reaction (1) represents the simple transfer of an organic chemical Y between 2 components, i and j, which may involve a specific interfacial site, I_{ij}. Y may also undergo a variety of transformation reactions either within the associated component (reactions (2) and (3) or at the interfact reaction (4)) yielding multiple products, denoted as U_n, Z_n, and Q_n. The rapid accumulation of dissolved organic matter at available marine interfaces (Bader, et al., 1950; Riley, 1963; Sutcliffe, et al., 1963; Parker and Barsom, 1970) is a good example of reaction (1). A large number of abiotic and biologically mediated transformations that can be represented by reactions (2) through (4) have been discussed by a number of investigators(Parke, 1968; Stumm and Morgan, 1970; Denny 1971; Nickerson, 1971; Owen, 1971; Crosby, 1973 and 1975).

Considering the extreme complexity of these interactions, it seems unlikely that the flow mechanism can be evaluated only from classical physical/chemical considerations within a reasonable time frame. It is therefore desirable to look for empirical parameters that 1) can be easily measured in the marine environment, 2) reflect net effects of the complex intermediary transport and chemical transformation steps, 3) are amenable to theoretical interpretations, and 4) can be used as universal indices in predicting the distribution of organic molecules in marine components.

The parameter that can meet the above criteria is the component concentration ration K, defined as

$$K_y = \frac{C_{y(j),x}}{C_{y(i),x'}} \qquad (5)$$

where $c_{y(j)}$ is the instantaneous concentration of chemical Y in component j normalized to some parameter x, e.g., wet mass, dry mass, etc., and $C_{y(i),x'}$ is the corresponding concentration of Y in component i. The choice of x and x' is arbitrary and represents the best quantitative measure of j or i for data consistency and uniformity when the measured K's are compared to the values predicted by theory. Although K does not provide information on the actual processess affecting the distribution of a given chemical among two components, it can serve as an empirical constant for that compound in an ecosystem where these processes are spatially uniform. This has some practical connotations in determining the concentration of Y in any particular component within a given region.

Since interfacial interactions for stable molecules are essentially limited to inter-component transfers (reaction (1)), K represents the instantaneous distribution or partitioning of Y between the marine components in question. With rapid exchange rates, K becomes a quasi-equilibrium constant for the transfer reactions. Therefore, we have selected the component concentration ration K as the most appropriate parameter to test the concept of chemical partitioning in the marine environment. We have applied this framework to the study of CBs in Puget Sound in an attempt to validate these concepts.

Suspended Particulate Matter

The component concentration data are summarized in Table 7. The values show a fairly uniform distribution within the Sound except for the Duwamish River which is higher by approximately one order of magnitude. The magnitude of K for CBs can be predicted based on a relatively simple fundamental equation derived from physical chemical principles (Pavlou and Dexter, 1977). The predicted K values are also included in Table 7. This model represents a first approach to defining the accumulation of stable organic molecules on marine particulate interfaces within a coherent theoretical framework. As such, it provides a guide to selecting appropriate ecosystem parameters which influence the distribution and bioaccumulation potential of CBs and other complex organic chemicals in the marine environment.

Zooplankton

The K values measured for zooplankton are presented in Table 8 and are reasonably constant over the range of spatial and temporal regimes encountered in these studies and appear to be independent of changes in faunal composition. The data suggest that the residue levels in ambient water and in the organisms (normalized to lipid) play an important role in controlling the degree of accumulation, particularly when lipid constitutes more than 2% of zooplankton fresh weight, thus providing further support to the equilibrium partitioning argument.

Implications of the Equilibrium Partitioning Concept to the Distribution Characteristics of CBs

The utility of K in the marine environment is not limited solely to the prediction of the accumulation potential of an organic compound. If one can ascertain that K is constant within an ecosystem, then the component fractionation can be expressed in a more useful form. We have applied this treatment to the evaluation of the CBs in Puget Sound.

Considering only the factionation of the CB residues in water and on phase j, the total concentration of CBs within a volume of water, $C_{t(w),v}$ can be expressed as

$$C_{t(w),v} = C_{y(w),v} + \sum_j C_{y(j),v} \qquad (6)$$

where $C_{t(w),v}$ is the concentration in water and $C_{(j),v}$ refers to the amount bound to j per unit volume of water. By definition

$$C_{y(j),v} = C_{y(j),d} \circ m_{j(w),v} \qquad (7)$$

where $C_{y(j),d}$ is the concentration of CB per dry mass of j and $m_{m(w),v}$ is the mass of j per volume of water. By combining these two equations and equation (5),

TABLE 7. SUMMARY OF REGIONAL MEAN K_d^N VALUES FOR SPM IN PUGET SOUND

REGION	DEPTH m	$K_{N\text{-}CB} \times 10^4$ N = 3	4	5	6	7	n	DATE
Duwamish River	3	1.64 *0.19*[a]	2.00 *0.51*	2.79 *0.70*	3.99 *0.94*	6.87 *1.72*	4	9-74
	8	1.79	1.60	2.25	3.71	4.05	2	9-74
DRDP	1	14.34 *12.17*	10.63 *7.58*	18.24 *15.75*	25.29 *17.50*	18.99 *2.20*	21	3-76
	8	8.04 *5.47*	9.88 *6.89*	12.54 *8.95*	22.24 *19.38*	19.21 *11.64*	35	3-76
Elliott Bay	3	1.06	2.86	3.16	4.07	2.75	3	6-73
	6	1.55 *0.34*	1.73 *0.28*	1.95 *0.35*	2.69 *0.62*	6.15 *2.02*	13	9-74
Hood Canal	1-20	2.07 *1.04*	2.32 *1.26*	2.96 *1.53*	2.26 *1.07*	NC	3	7-75
Average[b]		4.36	4.43	6.27	9.18	9.67		
Predicted		1.57	2.94	5.31	7.83	9.45		

[a]Values in italics represent one standard deviation of the K value.

[b]The unweighted means of all regional values.

TABLE 8. SUMMARY OF THE REGIONAL MEAN K_1^N VALUES FOR ZOOPLANKTON IN PUGET SOUND

REGION	n	$K_1^N \times 10^6$ N = 4	N = 5	N = 6	DOMINANT FAUNA
Elliott Bay[a]	6	1.06 ($\pm$0.81)	1.42 ($\pm$1.06)	2.17 ($\pm$1.64)	Euphasiids
Main Basin[a]	4	1.07 ($\pm$0.61)	1.90 ($\pm$1.25)	3.18 ($\pm$2.32)	Copepods
Whidbey Basin[b] (Port Gardner)	12	0.80 ($\pm$0.38)	1.09 ($\pm$0.51)	1.47 ($\pm$0.75)	Copepods/Euphasiids
Hood Canal[c]	3	0.98 ($\pm$0.56)	0.74 ($\pm$0.52)	0.43 ($\pm$0.32)	Ctenophores
Sinclair Inlet[b]	3	1.12 ($\pm$0.68)	3.61 ($\pm$2.02)	6.90 ($\pm$3.45)	Ctenophores
Admiralty Inlet[c,d] and Straits of Juan de Fuca	3	0.34 ($\pm$0.21)	0.28 ($\pm$0.18)	0.29 ($\pm$0.18)	Copepods
Average[e]		0.90	1.51	2.41	

[a]Cruise OA 608, September 24-27, 1974; [b]Cruise OA 552, November 5-8, 1973; [c]Cruise OA 665, July 14-17, 1975 (Clayton, et al., 1977; Pavlou, et al., 1977). [d]These values are based on the chlorobiphenyl concentrations measured at depths greater than 20 meters. [e]The unweighted means of all regional values.

the ratio of the CBs bound to phase j per volume of water to total CBs present in the same volume of water can be obtained as

$$F \equiv \frac{C_{y(j),v}}{C_{t(w),v}} = \frac{K_y m_{j(w),v}}{K_y m_{j(w),v} + 1} \qquad (8)$$

i.e., equation (8) states that the fraction associated with component i will be a function only of the magnitude of K_y and the ambient suspended load. Figure 5 shows plots of F (expressed in percent) versus $m_{j(w),v}$ for a number of K values superimposed on field and laboratory data for SPM. A good agreement with the predicted behavior is shown for both the laboratory and field determinations; the same argument can be applied to the biota, even though the concentration ratios for these components may be a somewhat complex function of the organism's physiology (e.g., percent lipid). The data obtained for zooplankton in Puget Sound are also included in Figure 5. Although the K values for zooplankton were greater than the ones for SPM, the dry mass concentrations of the former were usually within at least an order of magnitude lower than the corresponding SPM values. As a result, F for zooplankton is usually small; for these studies it never exceeded 4%. For the upper trophic level biota one can use the same argument; i.e., these systems will exhibit even a lower F value considering that there is a reduction of biomass in each succeeding trophic level (normally up to an order of magnitude; Riley and Skirrow, 1965) but with no commensurate increase in the K values. These observations have some important connotations regarding 1) the way the CBs and other similar organic compounds fractionate between water and suspended phases and between water and sediments, and 2) the validity of assuming a constant K.

For the first case, since the normal range for the suspended load encountered in coastal zones is within 0.5 to 10 gm^{-3} (Armstrong, 1965; Krank, 1973), compounds with $K \leq 1 \times 10^5$ will reside primarily in the water and not on suspended phases. For example the CBs which have K values within the range of 1×10^4 to 1×10^5 show an accumulation on suspended phases of less than 40% of the total CB load in water. Therefore, the spatial distribution of these chemicals will depend mainly on the hydrodynamics of the water column. Regarding their partitioning between water and sediments, the data support the following argument.

The dry mass of natural sediments is normally about 50% (= 5×10^5 g/m^3) of their wet weight at the water interface. As a result, a relatively large fraction of organic compounds, such as the CBs is expected to be absorbed to the solid matrix. However, their concentration, either on the sediments or in the interstitial water, will not vary greatly from the corresponding SPM and water concentrations in the overlying water column. This assertion is supported by the data in Table 9, where the CB concentrations for sediments can be compared with those for the SPM collected from the overlying water within a number of subregions in Puget Sound. The agreement is good, especially in view of the face that sediment values reflect a time-averaged concentration and may not show a one to one correlation with the SPM if their magnitudes in the water column fluctuate greatly. Therefore, the spatial distribution of the residues in the surface sediments should reflect the long-term, integrated flow patterns and

TABLE 9. COMPARISONS OF THE TOTAL CHLOROBIPHENYL CONCENTRATIONS IN MIXTURE SEDIMENTS SPM FROM SOME REGIONS OF PUGET SOUND[a]

REGION	SEDIMENTS (10^{-7} g/g)	SPM (10^{-7} g/g)
Duwamish River	12.4 $\pm$ 2.51 (14)	10.05 $\pm$ 2.84 (21)
Elliott Bay	1.64 $\pm$ 0.39 (9)	1.73 $\pm$ 0.24 (13)
Main Basin (Point Jefferson)	0.82 $\pm$ 0.03 (3)	0.70 $\pm$ 0.09 (3)
Whidbey Basin	0.63 $\pm$ 0.16 (5)	0.71 $\pm$ 0.09 (6)

[a]Values in parentheses represent the number of data points.

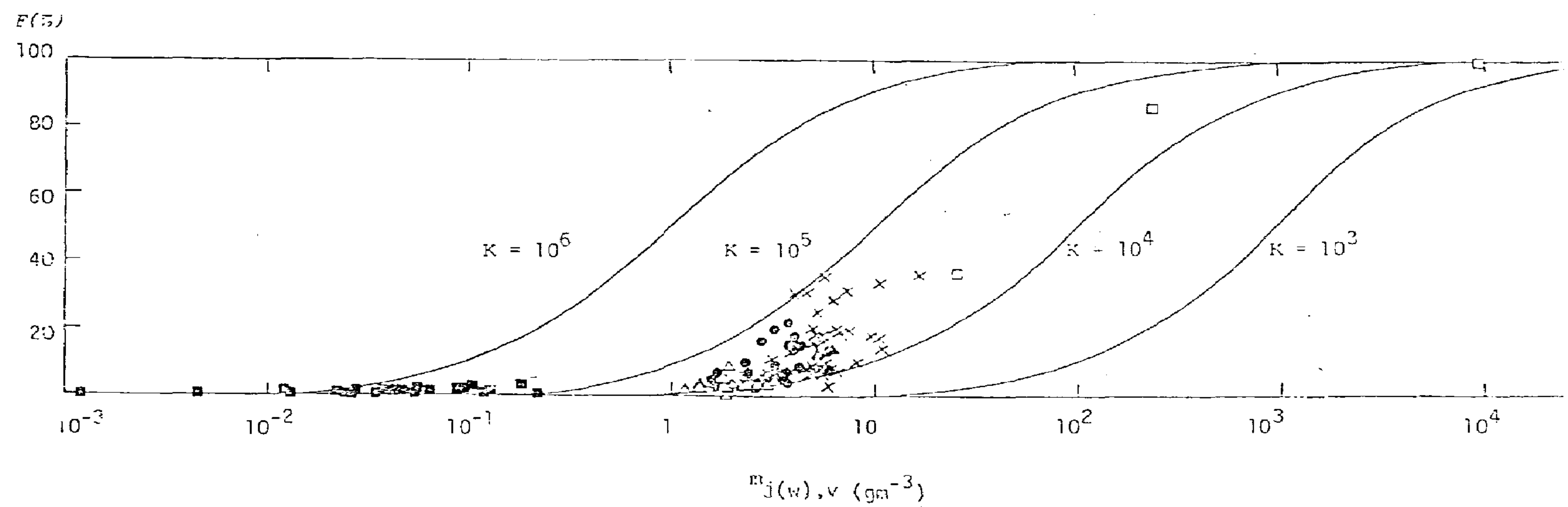

Figure 5. Plots of the per cent absorbed, F, versus the ambient suspended load, $m_{j(w)}$. The solid lines represent the theoretical predictions (equation 8). Measurements are included for SPM samples from the Duwamish River (SYOPS, ●; DRDP, X) and Elliott Bay (SYOPS, Δ), laboratory uptake experiments with phytoplankton, ▲, and resuspended Elliott Bay sediments, ☐, and for Puget Sound zooplankton samples, ■.

sedimentation properties of the overlying water. This is clearly illustrated in the distributions of CBs observed in Puget Sound, as well as in those of other coastal regions (Table 3). The values indicate that essentially all municipalities and industrial centers are apparent sources, although data for the main channel are insufficient to show this trend clearly. The detailed distribution in Elliott Bay (Figure 2), confirms the Duwamish River as a source. In this case, the pattern indicates a spreading out between the Duwamish Head and the middle of the bay; this trend agrees well with the prevailing circulation as shown in recent studies of the sediment regimes and biotopes of Elliott Bay (Harman, et al., 1975).

The above discussion together with the supporting data suggests that 1) sediments can provide a rapid assessment of the mean residue levels and dynamics in a system which receives stable organic chemicals like the CBs since, on a mass basis they will always contain higher concentrations of residues and can be easily sampled and analyzed. However, it should be emphasized that such data must be interpreted with care, because even though the residue levels in the sediments represent a temporal mean concentration, they depend on the sedimentation rate in the area, the depth of sediment taken for analysis, the particle size and the natural organic content. 2) Assuming temporal and spatial uniformity in the magnitude of K, the concentration of a compound measured in the water, SPM, or sediments at a given sampling site can be directly converted to the corresponding value in the other components through the appropriate K relationship. These conversions are often useful in generating a broader data base of easily comparable values for describing spatial and temporal trends. Therefore, within the limitations discussed above there is good evidence that the concentration of CB in SPM and sediment can be considered identical in a given region.

Toxicological Aspects

We have evaluated the results from a series of dose/response experiments performed with phytoplankton and zooplankton in the light of our present knowledge of the aqueous behavior of CBs (Pavlou and Dexter, 1977). The data obtained in this work and much of that in the literature should be interpreted with care. In general, our results agree with the literature data in postulating an acute toxicity threshold of approximately 10×10^{-6} g/l PCB for both phytoplankton and zooplankton. Similarly, we have documented more subtle effects on phytoplankton nutrient uptake and glutamate dehydrogenase (GDH) activity at an order of magnitude lower PCB concentrations. These levels were also observed to reduce the competitiveness of similar species in mixed cultures by other investigators. The toxicity thresholds determined in the batch culture experiments were converted to the corresponding concentrations in the phytoplankton by multiplying each water value by the appropriate K. When these values were compared with the ambient levels measured in Puget Sound, even for the most toxic PCB compound (2,5,2'-trichlorobiphenyl) the environmental levels are approximately two orders of magnitude below toxicity threshold. However, the ambiguity in the data due to deviations from equilibrium partitioning, phytoplankton resiliency and selective toxicity of the CBs does not justify establishing an absolute "safe" level. Recognizing these difficulties and although both higher and lower threshold values have been reported in the literature, it appears that a threshold of 1×10^{-6} gl^{-1} for total CBs and of 0.1×10^{-6} gl^{-1} for individual components are justifiable.

RECOMMENDATIONS FOR CRITERIA FORMULATION

Within the last few years the concern regarding the accelerated change of ecosystems resulting from the release of organic chemicals in the biosphere has been increasing steadily (Blodgett, et al., 1975; Neuhold and Ruggerio, 1977). This concern has been substantiated by recent congressional action through which the Toxic Substance Control Act was passed. Included in the Act was the ban on polychlorinated biphenyls.

Marine ecosystems, which constitute natural chemical sinks for anthropogenic materials, have been receiving substantial amounts of polychlorinated biphenyls, which in certain cases have reached hazard levels for both biota as well as public health. Therefore, it was not surprising that a major effort was placed to acquire scientific information on the input, distribution, fate, and toxicological aspects of these chemicals that was needed to establish realistic environmental strategies and regulatory controls. Extensive research has been conducted on CBs on a national level within the last decade. However, the informational feedback to regulatory agencies, upon which they can base their policy decisions, has been rather meager, mainly because of the lack of a comprehensive approach and the absence of perturbation considerations at the ecosystem level. Therefore, the task of establishing effective water quality criteria for CBs has been extremely difficult. Evidence of this state of affairs has been well documented in the most recent detailed review and criteria formulation for CBs prepared by Nisbet (1977).

Current Criteria

In view of the information obtained in our study and the conclusions generated thereof, it was deemed necessary to readdress the issue of criteria formulation. We have reviewed carefully the justification presented by Nisbet in establishing the 0.001 μg/l (1 ppt) level in water and analyzed our results within the regional environmental framework, as well as within the national picture. In principle, we do not disagree with the current criteria level, but we feel that applying a uniform value is unrealistic due to the high diversity and variable degree of complexity of aquatic ecosystems (physical, chemical and biological) and the absence of conclusive toxicological data. We are therefore proposing a modification of the current requirements by adopting a "best applicable criteria level" (BACL) approach which introduces a greater flexibility in establishing realistic requirements appropriate to a given marine region. Our recommendations are based on the considerations presented below.

The 1 ppt level was established in order to protect aquatic life and provide a margin of safety for consumer organisms. This requirement was based primarily on 3 types of experimental information:

1. bioaccumulation from aqueous media

2. response studies with organisms under varying dose levels in the water

3. physiological changes in organisms fed with contaminated food sources

For example, under certain CB dose levels in water, population shift in phytoplankton were observed and invertebrates showed reproductive anomalies, with some species exhibiting reduction in diversity. Bioaccumulation factors of 10^5 in fish were also measured in a limited number of experiments, thus suggesting that a potential accumulation in harvestable biota to levels of $\geq$ 0.1 ppm, from ambient water at the 1 ppt level, is not an unreasonable expectation. Assuming that such am amplification is possible and in view of independent observations indicating the CB concentrations within a range of 0.6 to 5 ppm in food caused reproductive dysfunction, metabolic anomalies, microsomal enzyme inhibition and mortality in mammals, the 1 ppt level was adopted as a reasonable limit (Nisbet, 1977).

However, there are a number of factors that were not considered which we feel argue against the strict enforcement of the 1 ppt level.

1. Upon examination of the current global background levels in water, it is apparent that in virtually all regions where data are available, including the Atlantic and Pacific Oceans; the 1 ppt level is consistently exceeded (Risebrough, 1976; Harvey and Steinhauer, 1976; Williams and Robertson, 1975; Pavlou, et al. 1974). Therefore, a uniform requirement below these equilibrium values is unrealistic.

2. Most toxicological investigations and toxicity data generated under laboratory control are of extremely limited applicability to actual environmental conditions. For the phytoplankton case, mixed populations have rarely been used; the variation of response to CB perturbation under natural environmental stresses (e.g., nutrient limitation) has not been considered; synergistic and/or antagonistic effects with other commonly encountered pollutants (trace metals, other organic compounds) or naturally abundant chemical constituents (nutrients, dissolved organic matter, etc.) have not been examined, i.e., the counterbalancing effects of biostimulation and bioinhibition and their implication to species competition and predominance within a given marine region under CB exposure are virtually unknown; the evaluation of long-term effects under continuous low level exposure to CBs in laboratory microcosms is lacking; a systematic biochemical assessment of metabolic processes (photosynthesis, respiration, enzyme regulation) to detect early symptoms of dysfunction has received limited attention. For organisms at higher tropic levels a similar situation exists; toxicity studies have been limited to acute effects under doses far above the natural levels; biochemical monitoring of enzyme function has been the exception rather than the rule; the effects of synergism, natural stresses (changes in the overall chemistry of their habitat, alteration of food sources and type) are largely unknown.

3. The present criteria do not account for the variation in the physical/chemical characteristics of the individual chlorobiphenyl components which in turn affect the toxicological behavior of these compounds. For example, in our studies we observed preferential toxicity for a number of PCBs to phytoplankton; the 3-CB were more toxic than the 5-CB by almost a factor of 10, but the 3-CB showed a lower bioaccumulation factor than the 5-CB. This observation has some important connotations to the criteria formulation, i.e., only the level for specific chlorobiphenyls might have to be reduced rather than the total CBs. We have developed an analytical technique throughout the course of these studies by which the concentrations of individual chlorobiphenyl components can be accurately

determined (Dexter and Pavlou, 1976). Consequently, it is possible to measure their concentration at a lower level than what would be acceptable for the whole mixture, if that component appears to be a specific toxicant to an organism.

4. The concept of biological availability and bioaccumulation potential from the ambient medium is not clearly understood. The bioaccumulation data currently available are as inconclusive as the toxicity information. Most of the measurements are of questionable quality due to the way the experiments were conducted, e.g., the range of concentrations normally used were close to the solubility values so that agglomeration effects could have biased the data. Therefore, bioaccumulation might be grossly overestimated. Furthermore, determinations of accumulation factors were at CB levels of approximately 3 to 5 orders of magnitude above environmental levels. Normalization of residue data to appropriate biomass parameters has rarely been considered as a factor that might eliminate the high variability in the measured accumulation factors. And finally, there is no evidence of any attempt to systematically examine the variables which control the biological availability of CBs in natural systems.

5. It has been our experience that the routine analytical error at the low ppt level is not much better than $\pm$ 50%. This does not account for the uncertainty introduced by spatial and temporal variability which may exceed $\pm$ 100% (Pavlou and Dexter, 1977). Therefore, it would be difficult to report a statistically significant concentration value at the 1 ppt level within any aquatic region without obtaining a high sampling density to account for both spatial and temporal gradients.

6. The physical, chemical, and biological constraints of a system may introduce a substantial uncertainty in the measurements due to spatial, temporal variability and biological patchiness, e.g., a stratified body of water such as a brackish estuary might have concentrations of CBs on one side of the pycnocline which meet the required level, while the other portion could grossly exceed it.

7. There is no evidence as to the cost effectiveness of enforcing the 1 ppt level versus the environmental and public health trade-offs regarding the use of a given ecosystem for near-term performance and long-term life support function.

Alternative Recommendations

Based on the previous considerations, we are presenting below a set of alternative recommendations for more realistic criteria levels.

1. Initiation of regional assessment consisting of: a baseline study on the physical, chemical, and biological dynamics of the ecosystem under study to determine turn over rates of energy and material, and the recycling capacity of limiting resources for biomass production; definition of processes which control the recycling capacity of resources within the region and which are sensitive to chemical stress; determination of background CB levels. This regional evaluation can be conducted by synthesis of existing data and/or implementation of a field program to acquire the necessary information for interpretations. In this manner a synoptic picture of the environmental dynamics of the region can be obtained, upon which the BACL can be based.

2. The ambient level for total CBs in water should not exceed 5 ppt, and the level for individual CB components should not exceed 2.5 ppt. We recommend these values since they are within the current range of the global levels of CBs. Those regions presently below the 5 ppt level should be maintained at the lower level and not permitted to exceed it.

3. CB levels in outfall effluents should not exceed 500 ppt for total CBs and 250 ppt for individual components. These limits are recommended as upper bound values (assuming a minimum dilution of 100/1 at the diffuser) to maintain the desired levels in ambient water within the vicinity of an outfall discharge.

4. Introduction of criteria levels for surface sediments is necessary since they constitute the long-term trap/source systems for all persistent and sparingly soluble organic compounds in the aquatic environment. We recommend that the total CB concentration does not exceed 500 ppb (dry weight basis), and the individual components do not exceed 25 ppb. These limits are based on the lower value (1×10^4) of the component concentration ration determined for sediments in our work, and are necessary to maintain the desired level in ambient water as recommended above. The sediments provide an excellent marine component for monitoring CBs, because the residues reflect a time-averaged profile of input levels in the overlying water without the bias of transient effects; they also provide a picture of the long term deposition pattern of suspended particulate matter containing these compounds. Areas with high sediment loads constitute a chronic source of CBs through desorption. This is particularly important in regions that have received direct but transient inputs of CBs from sources such as spills (Duwamish River), dumping of contaminated sewage (New York Bight, Long Island Sound) or dredge spoil (Elliott Bay). In such cases, a simple reduction or elimination of future imputs may not significantly reduce the ambient levels in water, at least until the sediment load is removed or buried (by cleaner silt build up) to a depth sufficient to prevent contact with the overlying water column.

5. At present, regions which have total CB concentration >5 ppt in water and > 50 ppb in surface sediments should be considered polluted. In such cases regulatory action and abatement of input sources are recommended based on cost effectiveness. Initiation of long-term monitoring of ambient levels in both water and sediments to establish seasonal variability and trends is also recommended.

Recommendations for Regulatory Action in Puget Sound

Based on the above criteria and the CB levels measured in the Sound we are considering the following areas under CB stress: Duwamish River, Elliott Bay and Sinclair Inlet exceed the required limits substantially. Commencement Bay and Whidbey Basin are within the criteria range and should be considered marginal cases. For the above areas we recommend 1) immediate identification and abatement of sources consistent with the standards recommended above, 2) announcement of the public health hazard from consuming contaminated food resources collected in these areas and 3) initiation of biochemical and histopathological monitoring together with the residue analysis of commercially important resident biota to assess levels of accumulation, physiological changes, metabolic anomalies and carcinogenic effects.

For the areas not on the critical list, a routine monitoring of ambient levels in water and sediments should be initiated to establish long-term trends and to ensure that these regions are maintained at acceptable levels. Regulatory action should be taken in a coordinated manner among the various federal and state enforcing agencies and the user organizations of these areas so that the most cost effective alternatives are adopted to revert the stressed ecosystem to background conditions.

RECOMMENDATIONS FOR FUTURE RESEARCH

Our recommendations for future research stem from our basic beliefs that the most effective manner to transfer technological information from a scientific perspective to a management and policy decision level is by adopting an ecosystems approach. These aspects have been amply stressed elsewhere (Neuhold and Ruggerio, 1977). What we would like to re-emphasize here is the necessity to adopt a rigorous and coherent framework to tackle the complex problem of ecosystem perturbation and its potential dysfunction induced by the continuously increasing input loads of organic chemicals. In order to maximize the utility of research results in formulating realistic and effective environmental decisions, the research should be conducted in a manner that informational feedback is continuously provided to the decision makers, who in turn can modify their regulatory process to the best benefit for both society and environment.

Field Program in Puget Sound

Although the field investigations conducted to date provide good "baseline" information regarding the distribution and dynamics of CBs in the estuary, certain aspects should be further examined.

All on-going input sources of CBs should be assessed quantitatively. Significant sources should be eliminated or appropriately modified to minimize their impact.

Studies should be initiated to determine the level of CBs in the major rivers of the Sound (Skagit, Snohomish, Stillaguamish) and the Straits of Juan de Fuca and off the Washington Coast. These rivers are the major fresh water input in Puget Sound; the Straits provide all the saline water and most of the volume exchange in the Sound. Elimination of inputs within the Sound may have little effect on the CB abundance in the region, if their oceanic source water is itself contaminated.

Research on Physical Chemical Exchanges

Our research demonstrates that the primary modes of transport of persistent organic compounds through an aquatic ecosystem, including accumulation on abiotic and biotic components, are generated by interfacial processes and are amenable to theoretical treatment. However, considerably more research is required to generate a universally applicable predictive model. It should be apparent that an accurate delineation of the factors affecting the biological availability of these compounds is of critical importance to the interpretation of toxicological data and to any realistic assessment of potential ecosystem dysfunction.

Toxicological Research

The studies which claim to have documented the toxic response of aquatic organisms to CB stress provide a good example of the prevailing deficiencies of the current toxicological research. The lack of a sophisticated and comprehensive approach which accounts for the physical chemical behavior of the test compounds, the parameter(s) chosen to measure a stress response, and the conditions under which the test organisms are maintained, seriously limit the utility of the available data in formulating realistic "safe" levels. We claim no expertise in biology or toxicology; nevertheless, we have gained enough experience during this study to offer a number of suggestions which we hope can be incorporated into a coherent strategy for evaluating the impact of organic contaminants in the marine environment.

At present, the establishment of water quality criteria results from the identification of a suspect compound followed by laboratory testing (bioassy analysis) to determine the lowest exposure level which will produce a response in test organisms. An extrapolation is then attempted to establish an environmental level which will produce no effect on the resident biota or their consumers. Although this approach is operationally simple, it would be more desirable to develop methods for the direct evaluation of the "health" of an ecosystem. For example, a "protocol" could be developed based on a pool of representative organisms from the region, maintained specifically for testing purposes (the microcosm approach). These organisms could be exposed to water samples from a suspect region and a stress analysis can be conducted. This technique may suffer from some of the same difficulties in extrapolating the data to predict the impact to natural resident populations, but would provide a means of quantitatively comparing water quality of various regions in terms of positive/negative response to a general stress.

Correlations between a variety of biological indicators of vital ecosystem processes such as histopathological changes, metabolism, photosynthesis and respiration, nitrogen utilization enzymatic rates and community structure within a suspect region and one which is similar in all respects except in the level of contaminants could also be used to determine if the contaminant load is inducing alterations of the system.

In summary, rather than basing regulatory action only on the concentrations of a few specific chemicals, one should examine whether system dysfunction is possible under the existing input load of stressers and then identify and regulate the compound or compounds which are causing the problem. Control should still be exercised over certain stable compounds, even in the absence of apparent toxicity, to protect consumer species and avoid long-term accumulation in the system. Furthermore, the methodology suggested here has the added advantage that the overall stress and synergistic effects from as yet unrecognized contaminants can be detected and intercepted prior to the onset of irreversible disruption of the system.

All toxicity experiments should be preceded by a careful determination of the pertinent physical chemical properties of the stresser. These must include: accurate determination of the aqueous solubility including its dependence on temperature and salinity, structure-activity correlations, determination of volatilization rates, and an estimate of the accumulation behavior. Only then can realistic levels and experimental designs for toxicological investigations be generated.

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ON NEARSHORE TRAPPINGS OF POLLUTANTS BY TIDAL EDDIES DOWNSTREAM FROM POINTS IN PUGET SOUND, WASHINGTON

Curtis C. Ebbesmeyer, Jonathan M. Helseth
Evans-Hamilton, Inc.

Clifford A. Barnes, John H. Lincoln, and William P. Bendiner
University of Washington

INTRODUCTION

Estuaries are often bounded by complicated shorelines. In many cases shoreline irregularities are associated with local nearshore flow patterns important in dispersing pollutants (Pritchard 1960; Okubo 1973). In Puget Sound, hydrographic charts show many irregularities such as prominent points and embayments (Figure 1). In a recent study using time-lapse photographic techniques and a hydraulic model of Puget Sound, McGary and Lincoln (1977) showed vividly that during major flood and ebb tides eddies formed downstream from prominent points. Qualitatively it is reasonable to speculate that pollutants discharged in or near tidal eddies at depth may be upwelled and recirculated toward shore.

Of particular importance in Puget Sound is the dispersion of 5 - 15 m^3/sec (1 - 3 x 10^8 gallons/day) of sewage effluent at approximately 73-m depth about 1 kilometer west of West Point (Figure 1). This discharge represents the great majority of Seattle's total effluent. In comparison with the natural environment, Barnes and Ebbesmeyer (1977) determined that the average estuarine flow northward past West Point equaled a discharge of about 30,000 m^3/sec (7 x 10^{11} gallons/day) or about 2,000-6,000 times the effluent discharged from West Point. Superimposed on the net seaward estuarine flow is the oscillatory tidal flow equivalent to ratios several times larger than those just noted. These ratios suggest that the effluent discharge is greatly diluted by the natural estuarine flow. However, in an experiment tracing dye injected into the effluent, Bendiner (1976) found concentrations in surface water sampled close to the beach near West Point up to 0.4 percent. This concentration corresponds to a dilution ration of 1/250, assuming that the source is effluent from the outfall ports. This value is roughly an order of magnitude larger than that which would be found if complete mixing occurred with the net estuarine flow. It is also considerably larger than found in dye patches well downstream from the diffusers.

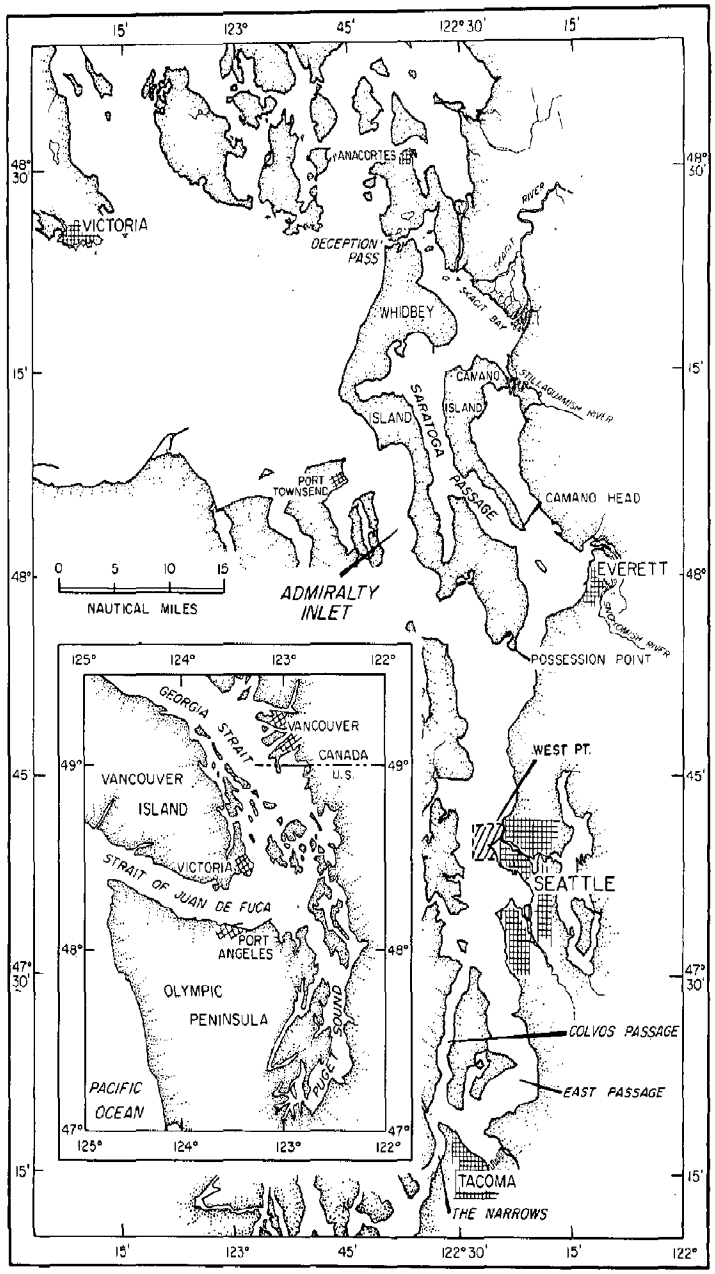

Figure 1. Puget Sound and study area

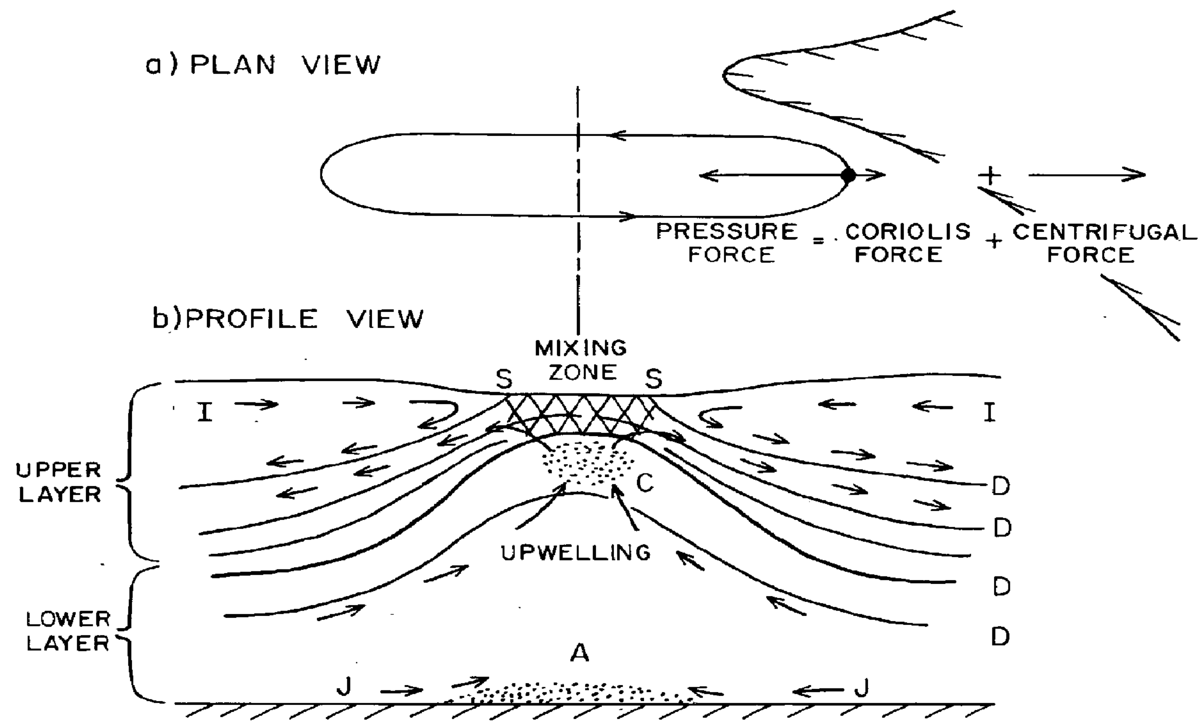

Figure 2. Hypothetical plan (a) and profile (b) views of counter-clockwise eddy. Notations: A, suspended sediment accumulated by secondary flow (J); C, flotsam accumulated by upwelling under pycnocline; D, isopycnals; I, lateral inflow/outflow induced by mixing; S, surface slicks.

It is worthwhile to explore possible physical processes by which the West Point effluent could be transported onto the beach. In this paper it is suggested that eddies forming south of West Point on flood tides may produce upwelling of effluent beyond that of its natural buoyancy. Once the effluent from the outfall has risen towards the surface, it can be transported shoreward by other processes such as those associated with wind and secondary tidal currents. Near shore, occasional pockets of water containing effluent may be trapped behind density fronts associated with insolation and local runoff.

Tidal eddies generally occur throughout Puget Sound near promontories and some are near other outfalls (e.g. Alki Point, see Rattray and Lincoln 1955). These locations have not received sufficient study to define the role of eddies in the movement and dispersion of effluent.

EDDY UPWELLING

Eddies long have been recognized as playing an important role in oceanic circulation. Numerous examples may be cited including:

1. rings pinched off the Gulf Stream (Fuglister and Worthington 1951),
2. the vortex formed above the Altair submarine volcano in the Atlantic Ocean (Defant 1940),
3. MODE (Mid-Ocean Dynamics Experiment) eddies now under investigation (Robinson 1976).

In general, productive fishing areas in the northern hemisphere are often located within counter-clockwise flows where both Coriolis and centrifugal accelerations are directed outward. There upwelled nutrients provide a base for intensive food chains.

Within small scale tidal eddies having high current speeds and radii on the order of meters to a few kilometers, the centrifugal acceleration may greatly exceed the Coriolis acceleration. In such cases, with peripherial speed decreasing with increasing depth, upwelling near the core can occur with either clockwise or counter-clockwise rotation. Figure 2 shows hypothetical profiles of circulation and density within a counter-clockwise tidal eddy in the northern hemisphere. Displacement of denser water above its static equilibrium level is driven primarily by the outward directed centrifugal acceleration, and combined with the gravitation acceleration, the isopycnals approach an equilibruim shape although it probably is never attained in this continuously accelerating tidal system. In addition to this doming of isopycnals is the buoyancy of the effluent which is less dense than the ambient water. Further upwelling occurs if the domed isopycnals rise and are eroded in strong shear zones often found near the primary pycnocline which is frequently near the surface in Puget Sound. The mixture tends to move laterally at a depth appropriate to its density. Contact with the bottom possibly results in secondary flows which would tend to accumulate suspended sediments in the eddy's core, somewhat as seen in a tea cup after stirring when tea leaves form a mound on the cup's bottom.

EXPERIMENTS NEAR WEST POINT

Recent experiments indicate counter-clockwise eddies formed on major flood tides south of West Point. Three types of studies were performed during summer and winter:

1. *drogue trajectories* (Ebbesmeyer and Helseth 1975) in order to track fluid parcels passing over the West Point outfall, groups of drogues were released on several occasions at the prevailing depth of maximum effluent concentration, and tracked during several flood tides (Figure 3). The term 'drogue' as used here refers to a drag moved at depth by prevailing currents, and attached by thin line to a surface float;

2. *dye distribution* (Bendiner 1976 and Karr 1975) in order to trace the effluent, Rhodamine B dye was injected continuously into the West Point effluent and its concentration measured along with temperature and salinity using a sensor package towed horizontally and cycled vertically; this yielded quasi-vertical profiles of dye and the associated density field (Figure 4). The dye can be detected at concentrations as low as 10^{-11} gm/cm^3;

3. *model experiments* (Lincoln 1976) in order to obtain a simulated view of horizontal movement and dispersion of effluent, dye was continously injected in a hydraulic model of Puget Sound and periodically photographed using a 16-mm camera (Figure 5). The model, constructed in the early 1950's, has a horizontal scale of 1/40,000 and a vertical scale of 1/1152, and is equipped with a tide-producing mechanism and means for adding regulated amounts of fresh and saltwater (Rattray and Lincoln 1955). Comparison with field data have shown the model representative of tidal currents near West Point (Lincoln 1976).

The results of the drogue and model experiments show that within the tidal area south of West Point the effluent spreads as filaments which ultimately break down into patches (compare Figures 3 and 5). The 2 patches nearest mid-channel maintained their identity during the ensuing ebb tide, whereas the patch nearest shore was drawn northward and quickly dispersed by strong current shears near West Point. Visual inspection of dye in the model suggests that occasional dye reaches shore as the nearshore patch moves northward. The dispersion pattern formed north of West Point on ebb differs markedly from that just shown south of West Point on flood. The ebb pattern is more finely dispersed consisting of a highly complex mixture of filaments and patches (Ebbesmeyer and Helseth 1975).

During the field dye experiments in a number of traverses made on flood tide, the sensor package passed through the West Point eddy. Figure 4 shows an east-west profile from results of Bendiner (1976) and Karr (1975). Isopleths of both density and dye concentration rise about 20 m toward surface near the center of the eddy shown schematically in Figure 2. A quantitative check on the consistency of the drogue trajectories and the interface slope of the eddy's density profile may be performed using the following equation (Defant 1961):

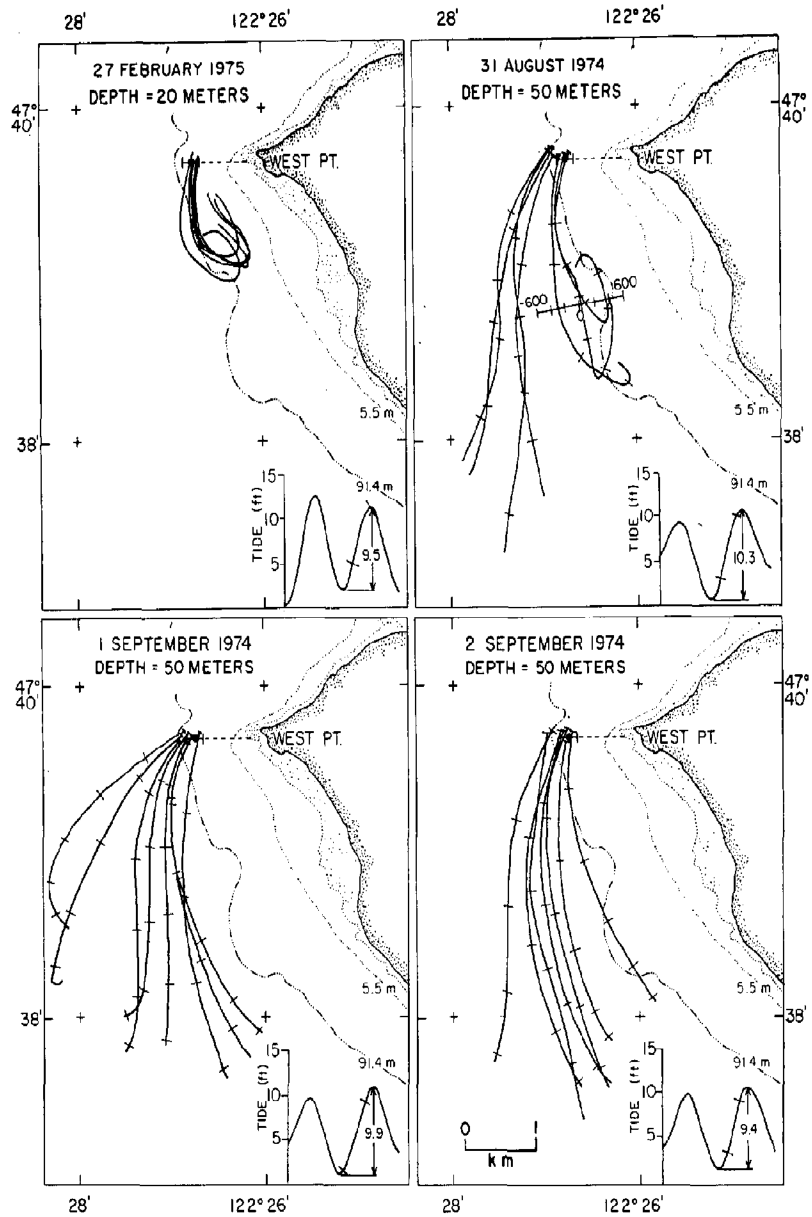

Figure 3. Drogue trajectories. Ticks on trajectories mark hour intervals. Ticks on tidal curves (insets) indicate trajectories' durations. Traverse at upper right corresponds to profiles in Figure 4. (Adapted from Ebbesmeyer and Helseth 1975).

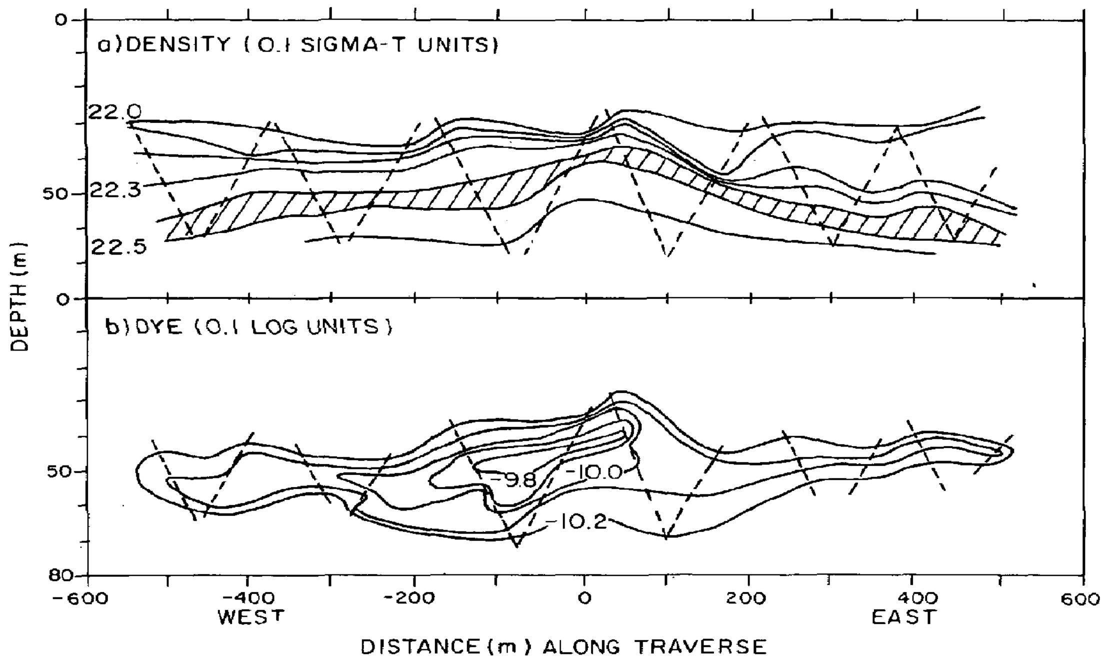

Figure 4. Density (a) and dye (b) profiles. Traverse is shown in Figure 3. Example: 22.0 sigma-t units = density of 1.022 gm/cm^3; and -10.0 log units = concentration of 10^{-10} gm/cm^3. Hatching denotes isopycnals characteristic of upwelling. (Adapted from Bendiner 1976 and Karr 1975).

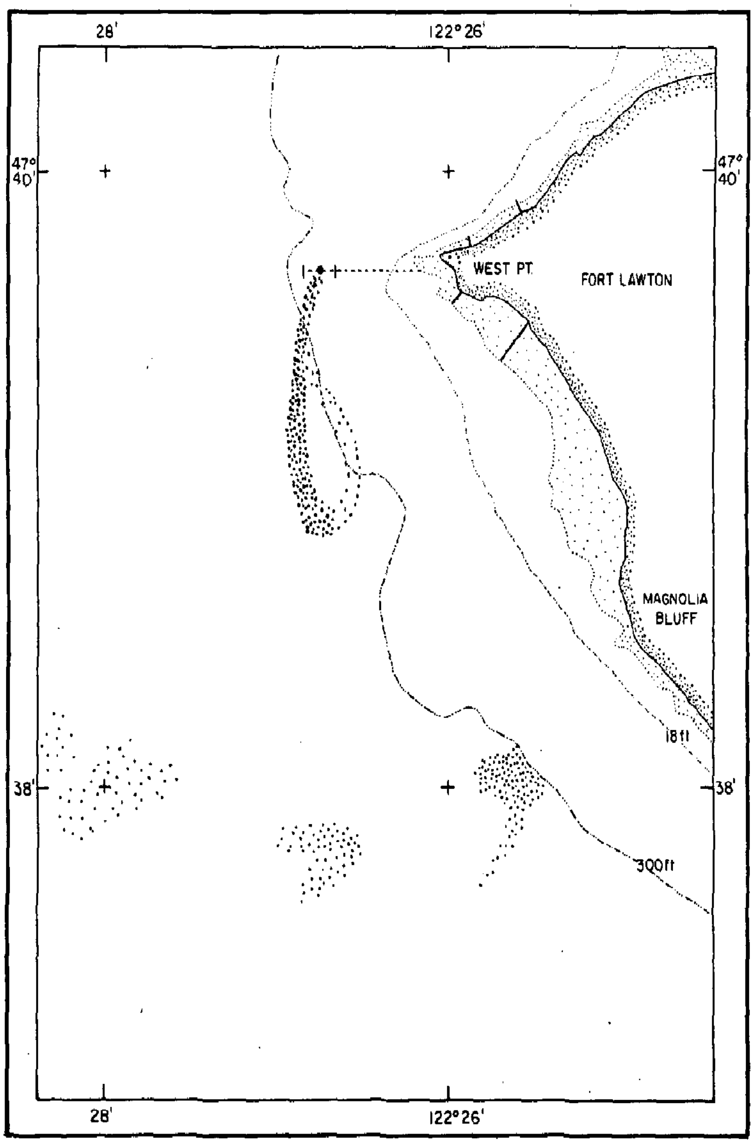

Figure 5. An example of dye patches formed during major flood tides. Ticks near West Point denote dye sampling locations. (Adapted from photographs by John H. Lincoln of dye injected into the Puget Sound tidal model).

$$\text{Interface Slope} = -\underbrace{\frac{2\,\omega\,\sin\phi}{g}\left[\frac{\rho_2\,v_2 - \rho_1\,v_1}{\rho_2 - \rho_1}\right]}_{\text{Effect of Coriolis Force}} + \underbrace{\frac{1}{Rg}\left[\frac{\rho_1\,v_1^2 - \rho_2\,v_2^2}{\rho_2 - \rho_1}\right]}_{\text{Effect of Centrifugal Force}} \quad (1)$$

where subscripts 1, 2, refer to the upper and lower layers, respectively, in the eddy as illustrated in Figure 2; and Table 1 describes the individual terms and gives values estimated using Figures 3 and 4. In equation (1) it is assumed that a two-layered flow is in steady rotation. Substitution of the parameter estimates into equation (1) yields a slope of 0.039, comparing favorably with a slope of .036-0.050 scaled from Figure 4. In this computation, the term representing the effect of centrifugal force contributes approximately 90% of the slope.

At change of tide there occurs considerable cross-channel movement, and the particular suite of conditions leading to the formation of the original eddy is lost. Alternating onshore and offshore movements can be expected. The probability of such movements should be considered in the interpretation of biological, chemical, geological and physical observations. Measurements are customarily taken near mid-channel, but not concurrently along the estuarine periphery.

EFFLUENT REACHING SHORE

A portion of the dye released during the summer experiment apparently reached shore at locations shown in Figure 5, whereas during winter no dye was detected at these locations (Bendiner 1976). Existing data are not sufficient to establish this variation as seasonal, or define pathways by which effluent may reach shore. Possibilities include onshore movement of the following:

1. nearshore patch observed in the model,

2. West Point eddy during change of tide,

3. effluent upwelled directly to surface during change of tide when current shears tend to be minimal.

Occasional boils visible at the surface over the outfall have been reported, although none were reported during the time when dye was observed nearshore. This condition or possible seepage from the outfall at shallower depth might lead to the relatively high concentration observed at shore.

In conjunction with these pathways, effluent may be trapped behind nearshore density fronts (Figure 6). Such fronts develop in shallow water between more rapidly moving tidal streams offshore and slowly circulating water near shore where heating effects associated with insolation are intensified. Elsewhere in Puget Sound a vivid example of nearshore heating has been observed in Skagit Bay where peripheral surface temperatures exceeded those at mid-channel by 3°C (Collias, Barnes and Lincoln, 1973).

Table 1. Descriptions and estimates of eddy parameters during dye and drogue experiments.

Parameters	Description	Estimate
ω	Earth's angular velocity	7.29×10^{-5} sec^{-1}
ϕ	Latitude	47° 40' North
g	Gravitational acceleration	980 cm/sec^2
ρ_1	Upper layer density	1.0220 gm/cm^3
ρ_2	Lower layer density	1.0226 gm/cm^3
v_1	Upper layer velocity	40 cm/sec
v_2	Lower layer velocity	20 cm/sec
R	Eddy radius	600 m

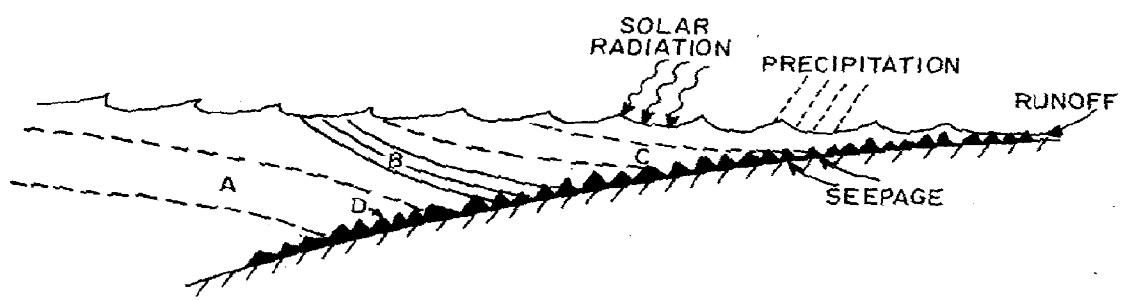

Figure 6. Hypothetical cross-section of shallow depths along periphery of Puget Sound. *Notation: A*, offshore water; *B*, pycnocline separating nearshore and offshore waters; *C*, lens of relatively low density water; *D*, bottom roughness elements.

CONCLUSION

Available evidence suggests that some of the effluent discharged offshore at depth may reach the intertidal and subtidal zones. In the West Point locale, one of the best documented examples of the dispersion of effluent from outfalls in Puget Sound, the data base is insufficient to define the pathways or quantify the exchange of water and waterborne substances between mid-channel and nearshore areas. The inshore regimes are rich in biological production, both primary and secondary, and are used extensively both in recreation and industry. The quality of nearshore waters is dependent to a large extent on inshore-offshore interchange which in turn cannot be understood short of intensive field programs devoted to the particular areas in question.

ACKNOWLEDGEMENTS

The work described here was supported by the Municipality of Metropolitan Seattle as part of its Puget Sound Interim Studies for Best Practical Treatment Alternatives. Contribution No. 968 from the Department of Oceanography, University of Washington, Seattle, Washington.

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UPDATING MONITORING ON THE DUWAMISH RIVER

Ruth W. Shnider
URS Company

This presentation is concerned with a discussion of the methods of water quality monitoring carried out on the Duwamish River, and those characteristics of the river and its estuary that adversely affect monitoring equipment, thus increasing normal monitoring effort and cost. Current technological developments are noted that suggest a potential for updating monitoring techniques and making them more cost-effective.

Water quality of the Duwamish River directly affects that of Elliott Bay and Puget Sound. Outfalls of the METRO Renton Treatment Plant and several industries empty into the river. Hence knowledge of the water quality of the Duwamish is a necessary part of the examination of the impact of man on the waters of Puget Sound. The Duwamish water quality monitoring network was established in 1963 by the United States Geological Survey in cooperation with METRO. It originally consisted of 4 fixed water quality and 5 gaging stations along the river, from just above the Renton Sewage Treatment Plant outfall into the Upper Duwamish (Green River), to Elliott Bay. Funding was, and still is, 50-50 by METRO and the Survey. The network satisfies primarily an ambient objective: to provide a continuous record of the change in the parameters over time, to assess the effect of the changing waste disposal in the estuary, and to obtain data for verifying the water quality simulation model of the river (and the location of the salt wedge).

The locations of the 5 fixed submersible pump-type stations with float devices that are currently in use are shown in Figure 1. Most of the stations are still at their original locations, which were selected intuitively on the basis of population, associated industry, and the requirement to locate the salt wedge. Meteorology and topography were not considered.

Parameters measured at each station include temperature, turbidity, dissolved oxygen concentration, specific conductance, and pH. Both surface and bottom recordings are taken at the stations located at the Spokane St. Bridge, and at the 16th Ave. South Bridge, where the probes are 1m below the surface and 1m above the bed. Solar insolation, also, is measured at the East Marginal Way Station. Mobile surveys are used to supplement the data from the fixed stations.

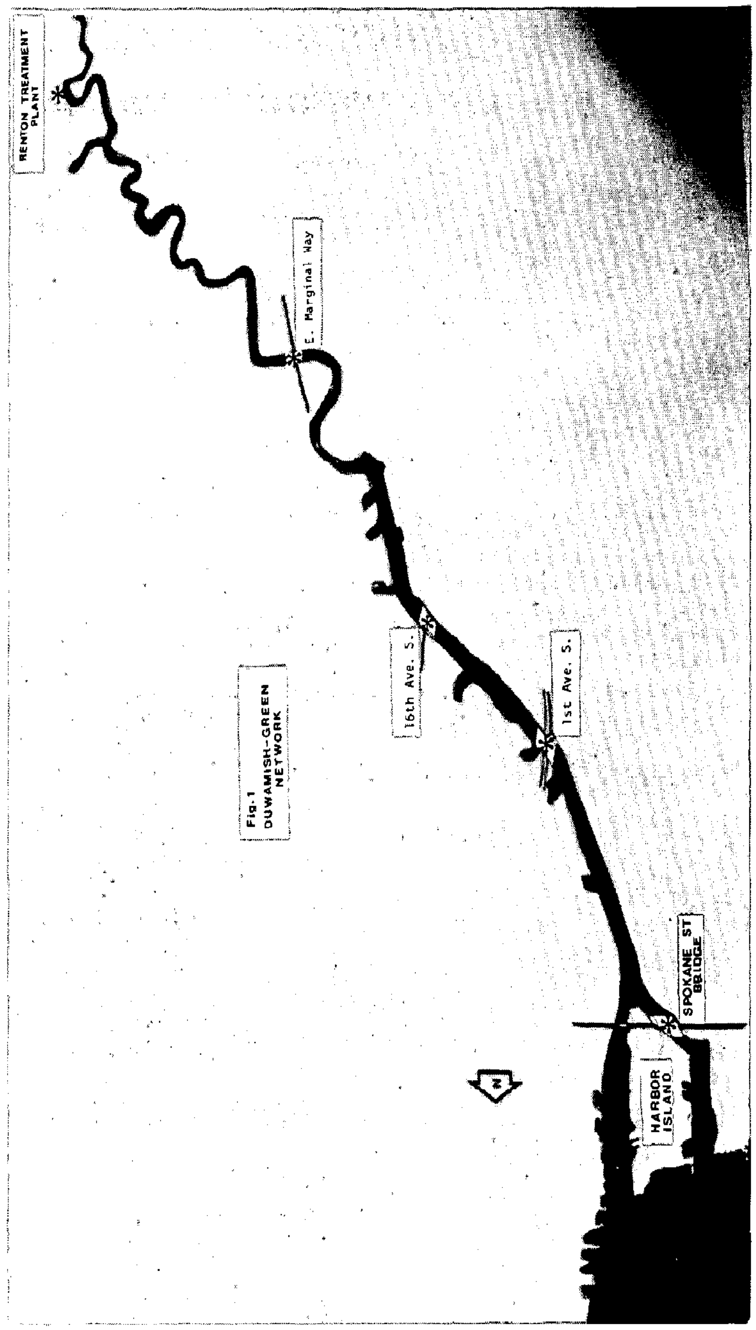


Fig. 1 DUWAMISH-GREEN NETWORK

Maintenance problems have plagued the data collection effort, resulting from several characteristics of the Duwamish environment that adversely affect the equipment. At the 3 lower stations, tidal action changes the salinity from fresh to salt water. As a result, electrolytic effects on the pumps are such that they must be replaced on a regular maintenance schedule, every few months. In the summer months, periphyton and algae collect on the sensors to such an extent that the sensors must be cleaned twice weekly in order that the data be considered reliable. Because these sensors are extremely sensitive, they require inspections and calibration at least weekly the rest of the year. The need for such frequent maintenance contributes to the difficulty and cost of the monitoring program. For instance, according to the U.S. Geological Survey, in 1973, the cost to operate 4 fixed stations was $43,700, of which maintenance and calibration costs were over $32,000. The costs of equipment replacement are not included.

In comparison, the Ohio River Valley Water Sanitation Commission (ORSANCO) operated a robot monitoring network comprised of 19 remote stations, at a cost of $41,000 in 1974. The cost does not include instrument depreciation. Furthermore, the ORSANCO robot monitors contain sensors for more parameters than those measured on the Duwamish, since they measure dissolved oxygen, specific conductance, temperature, pH, chloride, oxide-reduction potential, and solar radiation. They are maintained regularly at 2 week intervals under contract with the Schneider Instrument Company of Cincinnati, Ohio, who designed the system. Signals from the monitors, which are sent via a leased-wire service, are received at ORSANCO headquarters in Cincinnati, and are monitored at 2 minute intervals.

It is thus apparent that the ORSANCO network is far more cost-effective than that of the Duwamish River. However, ORSANCO monitors are operating in an entirely fresh water system, whereas in the Duwamish, the estuarine environment creates additional instrumental problems.

In the following paragraphs, several applications of modern technology are offered for consideration as being potentially useful in providing a more cost-effective monitoring effort.

The first alternative to the present system that is suggested is the modification of in situ equipment to allow more effective operation. Consultation with equipment manufacturers would be required to determine whether they could provide modifications that would allow successful and cost-effective use of their robot monitors in estuarine conditions.

Difficulties encountered during in situ monitoring, particularly in the estuarine environment, suggest examination of remote sensing potentialities. Remote sensing equipment has been used to advantage in many cases, where the equipment is mounted in aircraft that overfly areas of interest, such as power station cooling ponds, or harbors. However, the cost-effectiveness of such a procedure would not be an improvement over methods currently in use. If one observation were sufficient, or if long intervals between observations were acceptable, it would be possible to employ data from satellite observations. For instance, (Reference 1), through analysis of data from the Multispectral Scanner mounted on the ERTS-1 (Earth Resources Technology Satellite), it was possible to observe sewage sludge, acid waste, suspended solids and the major water mass surface boundaries of these pollutants dumped in the New York Bight. The scanner collects data in 4 spectral bands from 0.5 to 1.1 micrometer, and the satellite orbit provided repeat coverage of the study area every 18 days, thus providing information to allow calculation of the surface movement of the wastes. Adaptation of remote sensing techniques to the Duwamish network may offer some possibilities of cost-effective monitoring.

One remote sensing technique that could provide information on temperature of the Duwamish is use of the Airborne Infrared Line Scanner. This equipment has been used, mounted in aircraft, to scan the surface of a water body, recording temperature and circulation data on magnetic tape, for subsequent detailed processing. Infrared scanning presents two potential uses. The first potential is the use of a radiometer, such as the Barnes Engineering Company PRT-5, with a 10° field of view. Such radiometers could be fixed beneath the bridges that cross the river, and would measure the temperature of the top 1-3mm of water. According to information obtained from the NASA Ames Research Center, such a surface measurement is representative of the column temperature, if the water is moving at a reasonable velocity. Furthermore, since atmospheric attenuation of infrared increases with altitude, the bridge location would minimize such attenuation.

A second application of airborne infrared scanning has been developed by Daedalus Enterprises, Inc. of Ann Arbor, Michigan. This method combines an airborne infrared scanning instrument with the highly accurate Daedalus DIGICOLOR process to provide thermal contouring of water bodies. The Daedalus procedure on which information is available is expensive and appears impractical for use on the Duwamish. However, a brief review of the results are presented, since the company claims that thermal discharges or seepages into rivers and lakes have been successfully mapped, and many have been mapped for each tidal cycle, or periodically, to assess effects of factors that may influence a discharge. The company solicits the opportunity to answer questions on specific problems, and it is possible that the process could be adapted for use in monitoring on the Duwamish. To map the Commonwealth Edison's Powerton Station cooling pond, the scanner was mounted in a twin engine Beech aircraft that made 6 passes over the pond with a 36% sidelap, at an altitude of 1,500 feet. The circulation pattern of the Powerton cooling pond is shown in Figure 2. Each color in this pattern represents a 3°F thermal range, commencing with red and continuing through magenta, as illustrated. Thus, the pond exhibits a temperature drop of 18°F from the point of discharge (white) to the intake point (black). The system is also capable of temperature sensitivity mapping in 1°F intervals. The color mapping can then be converted to a contour map of water temperature, if desired.

An airborne differential radiometer has been demonstrated to be a sensitive real-time detector of surface chlorophyll and temperature in marine and fresh waters, as described in articles by John C. Arvesen, et al., of Ames Research Center, NASA, Moffett Field, California (Reference 2). The method is based on the correlation spectrometer principle, by configuring the instrument to correlate to specific characteristics unique to the parameter to be detected. All phytoplankton posses chlorophyll *a* as one of the chromophores that absorb solar energy. For a large number of phytoplankton species, as shown in Figure 3 (an illustration of Arvesen's report), there is a maximum absorption in the blue, at about 440 nm, due to chlorophyll, there is carotenoid absorption into the green, a relatively transparent region between 530 and 650 nm, and another absorption maximum at 680 nm. This characteristic spectral signature is used in the

SCALE-CORRECTED DIGICOLOR
MASTER MOSAIC OF COOLING POND

FIG. 2

correlation method to detect phytoplankton. The intensity at a reference wavelength located at the absorption maximum. Variations in the concentration of phytoplankton pigments primarily affect the intensity at the sample wavelength, resulting in a signal output from the differential radiometer proportional to the apparent absorption band strength. An infrared radiometer was used to provide water surface temperature as a conjugate measurement to chlorophyll. The results of approximately 50 comparisons between remote measurements of chlorophyll from an aircraft and laboratory analyses are shown in Figure 4, also taken from Arvesen's report. The data cover a wide range of chlorophyll and turbidity levels.

Analysis of simultaneous measurements that were made of chlorophyll and temperature in Howe Sound, British Columbia, are illustrated in Figure 5, which is from Arvesen's paper. This plot demonstrates the correlation found between surface temperature (a physical property of the water) and chlorophyll (a biological property).

This last described technology is of particular interest because, according to Mr. William Haushild of the U.S.G.S., the early mobile surveys of the Duwamish indicated plentiful phytoplankton, also evidenced by the accumulations on the sensors. The techniques discussed above required the installation of equipment in a Cessna 401 aircraft (Fig. 6), and overflying the area. Such monitoring would be an expensive undertaking, on a continuing basis. However, it is possible that the techniques involved could be applied to monitoring the Duwamish by the use of fixed monitors, installed beneath the bridges over the river. Comparison of results between stations may serve to locate causes of changes in water quality.

Another potential measurement is the use of color time-lapse photography in cameras positioned beneath the bridges. Such photography would allow the detection of temperature and sediment load, which can be correlated with the color. Details of the camera mounting, timing devices, and protection can be readily resolved.

Of all the technologies noted above, only the robot monitors would provide all the data presently gathered at the fixed stations, and the feasibility of the use of modifications of these sensors has not as yet beeen demonstrated. It can be argued that techniques providing only one or two categories of data are inadequate replacements for the multi-parameter data currently available at fixed stations. However, installation of equipment for one or more of the suggested techniques at locations above the existing stations should provide correlations between the presently measured in situ data and temperature, circulation, sediment load, and chlorophyll concentrations measured from the bridge locations. It is also possible that infrared data can provide some information on the organics in the water, and that correlations could be developed from simultaneous measurements of the temperature, organics, and dissolved oxygen concentrations. In addition, correlations should be made with the numerical model of the salt wedge reach of the Duwamish River Estuary (Ref. 3). This model was used to calculate distributions of salinity, temperature, chlorophyll a concentrations, biochemical oxygen demand, and dissolved oxygen concentrations in the Duwamish River Estuary, to estimate effects of changing sewage-effluent discharge.

Furthermore, analysis of the large amount of existing historical data may indicate that the frequency of some analyses can be reduced. For instance, U.S.G.S. examined bottom sediment at the Renton junction, and stopped taking samples when enough data were available. Results of the presently conducted mobile surveys may prove to be adequate checks, in combination with correlations developed for the remote sensors.

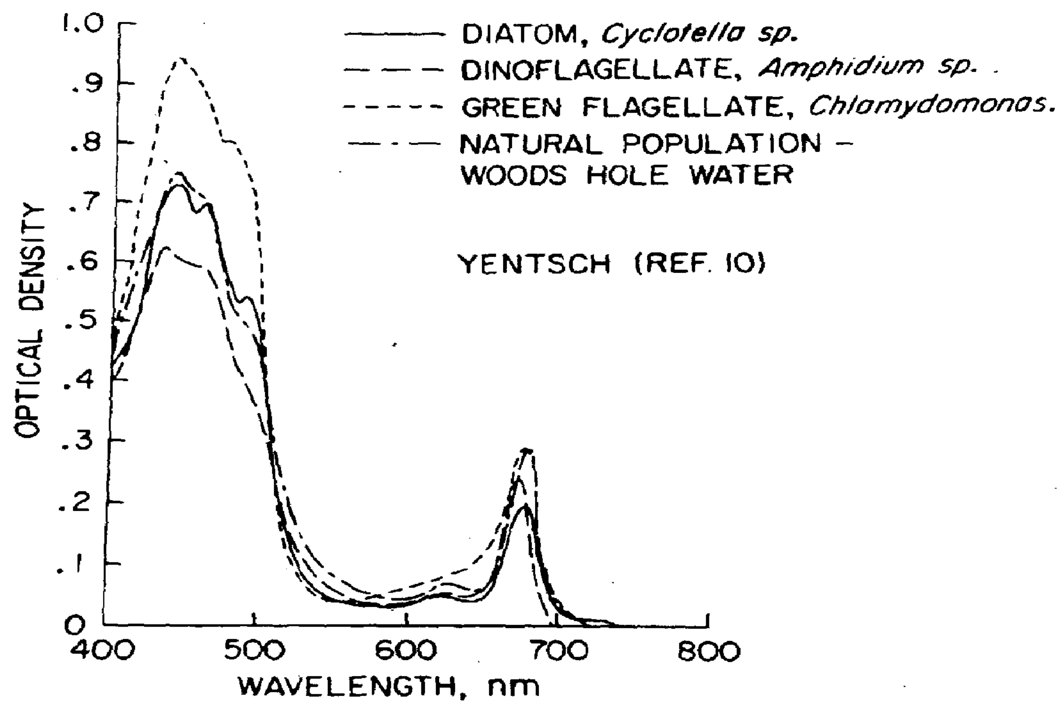


FIG. 3 Absorption spectra of a variety of marine phyto-plankton.

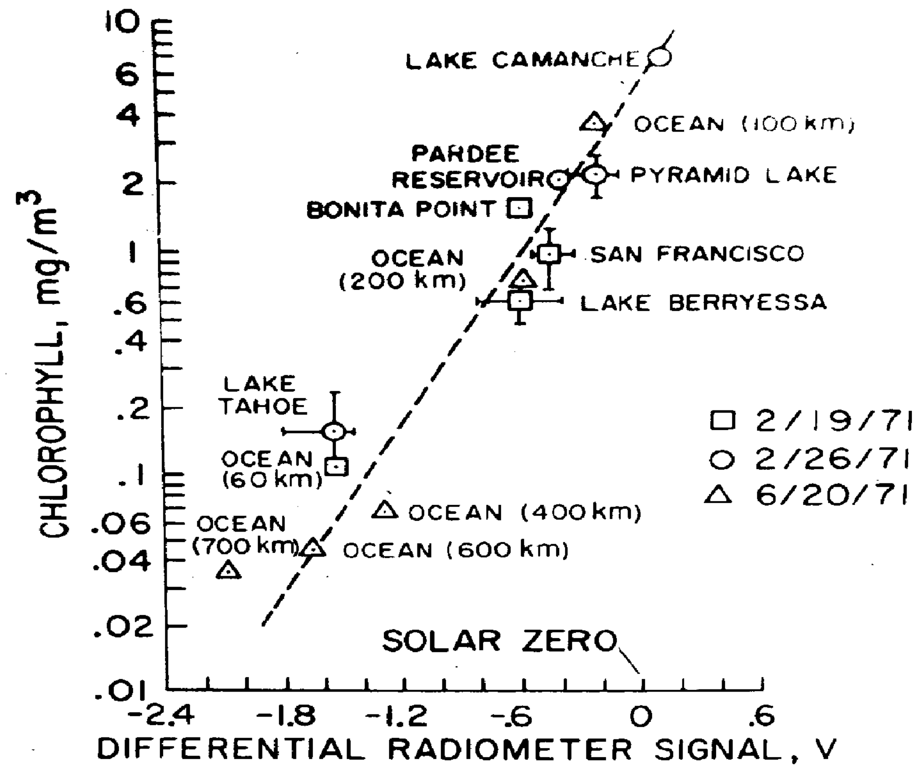


FIG. 4 Remote sensing compared with laboratory analysis.

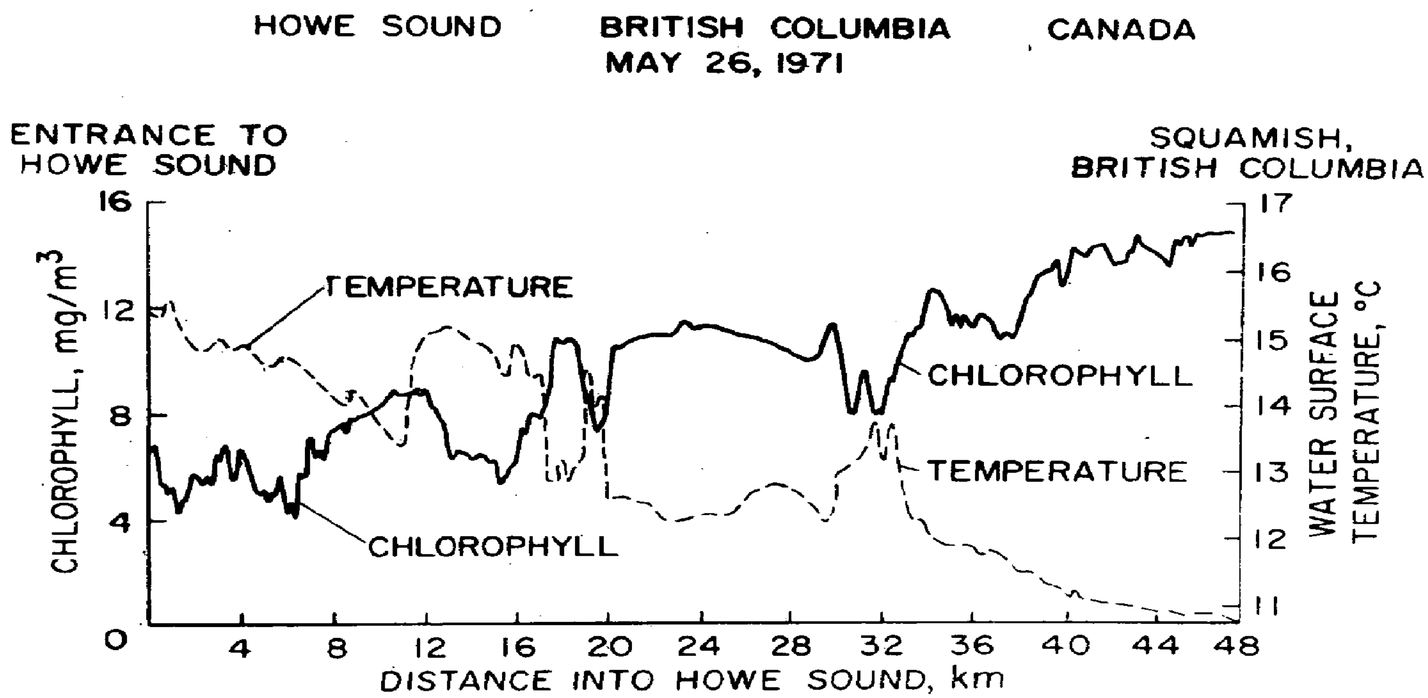
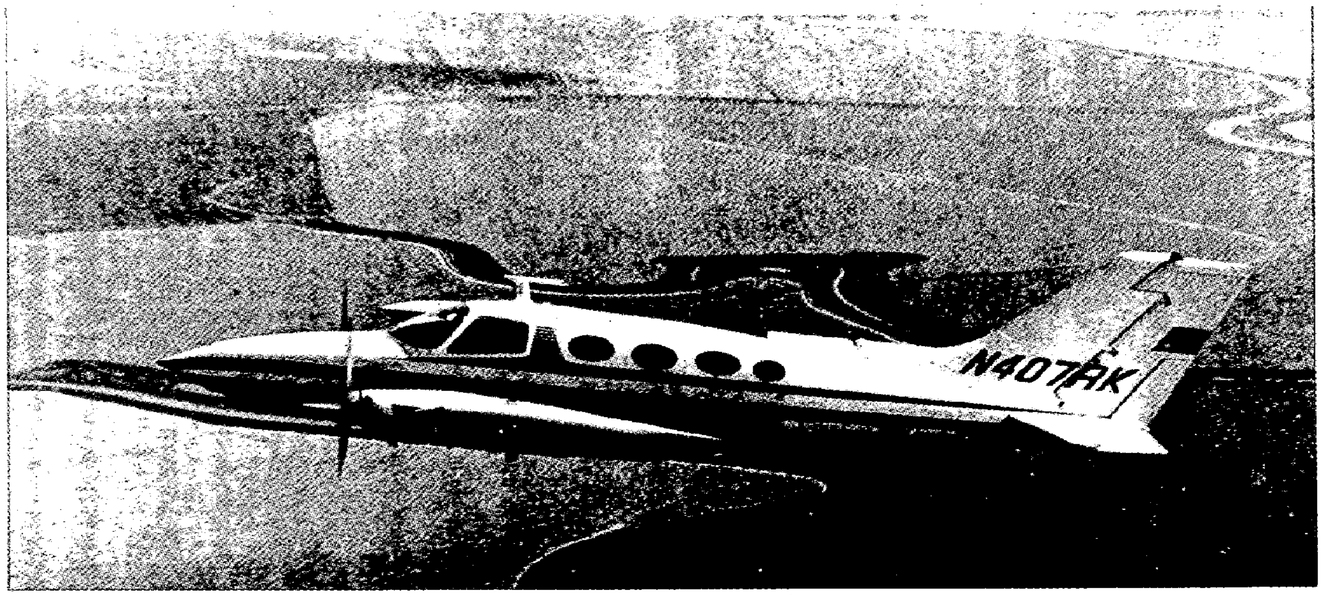


FIG. **5** . Chlorophyll and temperature correlation in Howe Sound, British Columbia, Canada on May 26, 1971.



DIFFERENTIAL RADIOMETER (0.3 TO 1.0μ)
SPECTRORADIOMETER (0.3 TO 1.0μ)
INFRARED FILTER RADIOMETER (2 TO 20μ)
HASSELBLAD CAMERA
DATA ACQUISITION SYSTEM

FIG. 6 Cessna 401 aircraft used for remote sensing.

The alternative techniques suggested would require investigation and trial to determine their usefulness. If proved feasible, they would provide more cost-effective methods of monitoring the Duwamish.

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INTERTIDAL DISPOSAL OF DREDGED MATERIAL IN WASHINGTON ESTUARIES

Richard Albright
Washington State Department of Game

INTRODUCTION

Throughout man's history, estuarine ecosystems have been subjected to various forms of his pollutants. Their natural resources have attracted a high percentage of the world's population to areas adjacent to or on what was once estuarine lands. The need for more and larger navigable waterways and additional agricultural or industrial land became a necessity as technology progressed and populations increased. It seemed inevitable that man would see fit to combine these two problems into a common solution; to use materials dredged from creation or maintenance of navigable waterways to create agricultural and industrial lands by "reclaiming" tidal flats. As agricultural and forest practices began to cause increased problems with erosion, the need for dredging became more imperative, with greater amounts of material to be disposed.

Several works have discussed the biological resources of estuaries (Lynam, 1972; Green, 1968; Lauff, 1967; Knox and Kilner, 1973). As a result, increasing concern has developed over the impact on our biological resources resulting from the alteration of estuarine lands. In early 1974, the U.S. Army Corps of Engineers (USACE) contracted the Washington State Department of Ecology (DOE) to conduct a study on the effects of dredging on the environment in Grays Harbor, Washington. DOE in turn subcontracted the Washington Departments of Game and Fisheries and staff members at Grays Harbor College to perform most of the actual field work. The Deparment of Fisheries investigated the impacts of dredging on Dungeness crabs and performed bioassays on both salmon and oysters. Grays Harbor College contributed work on the effects on water quality and on heavy minerals and grain size distributions in the harbor. DOE performed a literature review on hydrodynamics of the harbor and conducted an underwater investigation of a disposal area. The portion of the study contracted to the Department of Game included assessment of impacts on fish, mammals, birds, vegetation and benthos. Although portions of the study included observations on several types of disposal areas, my remarks will be based on the impacts of disposal of intertidal, unconfined dredged material.

Dredging has occurred in Grays Harbor since at least 1905. Accurate records of quantities dredged and disposal sites have not been kept until recent times, but extensive portions of the harbor have been disposed on at some time (K. Willin, Port of Grays Harbor, personal communication, 1975). Since 1940, approximately 16 km^2 (3954 acres) of intertidal habitat have been lost. Plans exist by the Port of Grays Harbor to remove another 25-30 km^2 (6200-7400 acres) of tidelands (Port of Grays Harbor, 1975), although these proposed fill areas must first be approved by the Grays Harbor Estuary Planning Task Force, comprised of representative from 5 cities in the area, the Port of Grays Harbor, regional and county planning commissions, and several state and federal natural resource agencies.

INTERTIDAL DISPOSAL IN GRAYS HARBOR ESTUARY

The intertidal disposal area is designated by the USACE as Site E (Figure 1). As disposal had occurred there before the study began, the use of control or contrast sites was used to evaluate biological impacts. The 2 contast areas are designated as Sites E-1 (just east of Site E) and E-2 (across the navigation channel from Site E to the south). The term 'contrast' is preferred as variations between these areas and the disposal site are unavoidable. Contrast areas used in the fish sampling were different, being located both to the north and west of Site E (Figure 2). Benthos and sediment sampling stations were located at Sites E, E-1, and E-2 (Figure 3).

A total of 206,415 m^3 (270,000 yd^3) of dredged materials were deposited on Site E in the spring of 1974 by means of a hydraulic dredge. Another 204,160 m^3 (267, 050 yd^3) were deposited in 1975 during the course of this study. As a result of the 1975 deposition, elevations above mean lower low water (MLLW) were drastically altered (Figure 4). At the 9 benthic sampling stations for Site E, the average increase in elevation was +0.92 m. There was also an apparent change in sediment type which occurred at Site E. Coarser sediments were found in the middle of the outfall area where elevations were highest. This was because finer sediments, which are more subject to dispersion by wave action, were carried away from the outfall, leaving the coarser sediments behind. This fits the general pattern in Grays Harbor of a gradation from coarser sediments in higher intertidal areas where wave action is greater, to finer sediments in lower intertidal areas (Dr. J. Phipps, Grays Harbor College, personal communication, 1975).

The impact on the benthic community was severe (Figure 5). Following disposal, the number of species present in Site E was a minimum of 66.0 percent lower than at the 2 contrast sites (E-1 and E-2). Mean numbers of individuals and biomass per station were a minimum of 96.7 percent lower than at the contast sites. A change in species composition accompanied the changes in elevation and sediment composition. The gammarid amphipod, *Corophium stimpsoni*, the most numerous benthic organism in the inner-portion of Grays Harbor, was particularly affected by the disposal operation. High elevation and coarse sediments at Site E were responsible for low densities. At Site E-1 the density of *Corophium stimpsoni* also showed the same decrease above +2.13 m (MLLW). The change in elevation is expected to be permanent. Benthic sampling at Site E after 1974 indicated that recolonization was inhibited at approximately +2.13 m to +2.44 m. After disposal in 1975, 8 stations were above +2.44 m in elevation, and 5 were +2.74 m or higher. Thus it is expected that recolonization in much of the disposal site will be greatly inhibited and the impact on the benthic community is expected to be permanent.

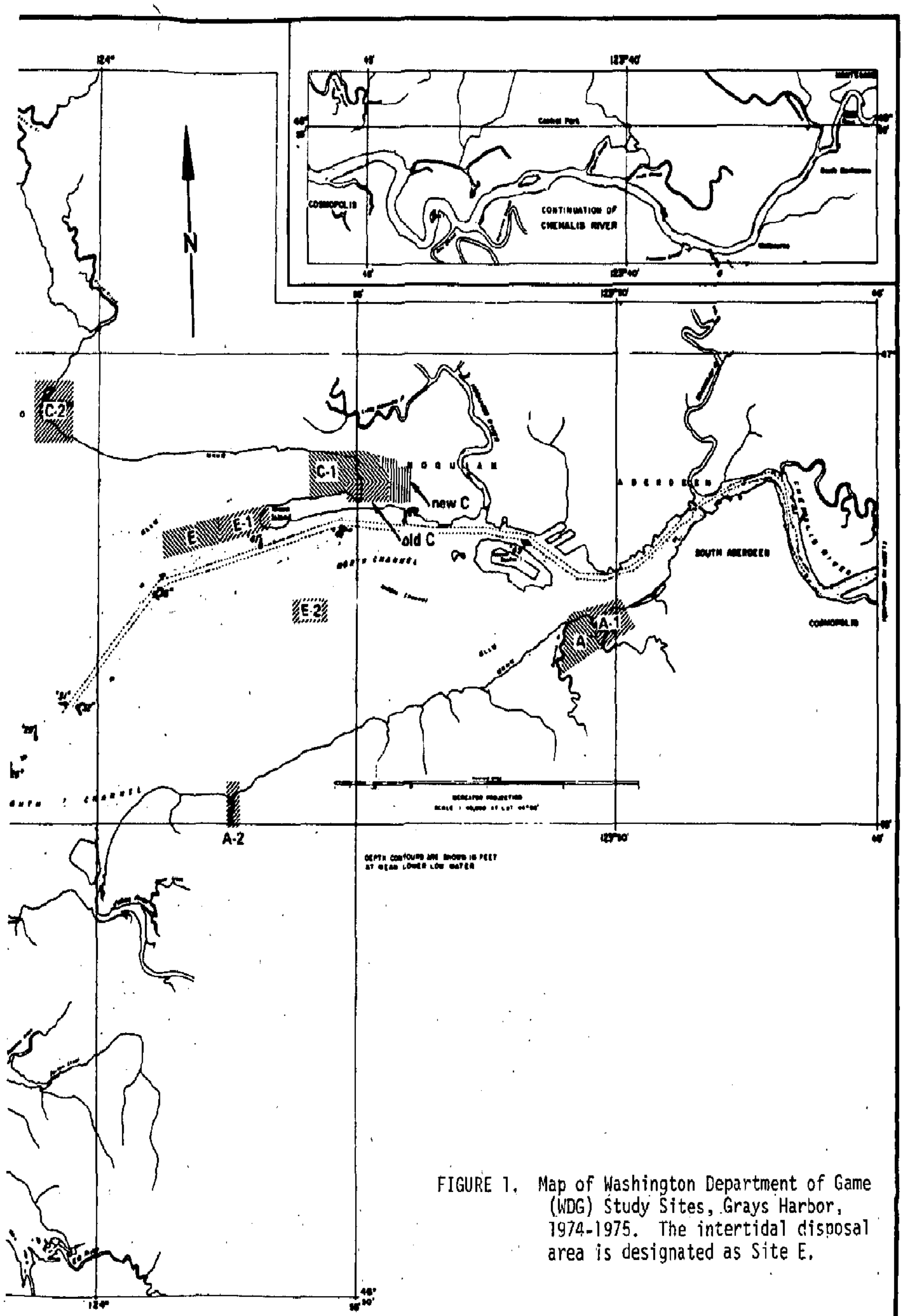

FIGURE 1. Map of Washington Department of Game (WDG) Study Sites, Grays Harbor, 1974-1975. The intertidal disposal area is designated as Site E.

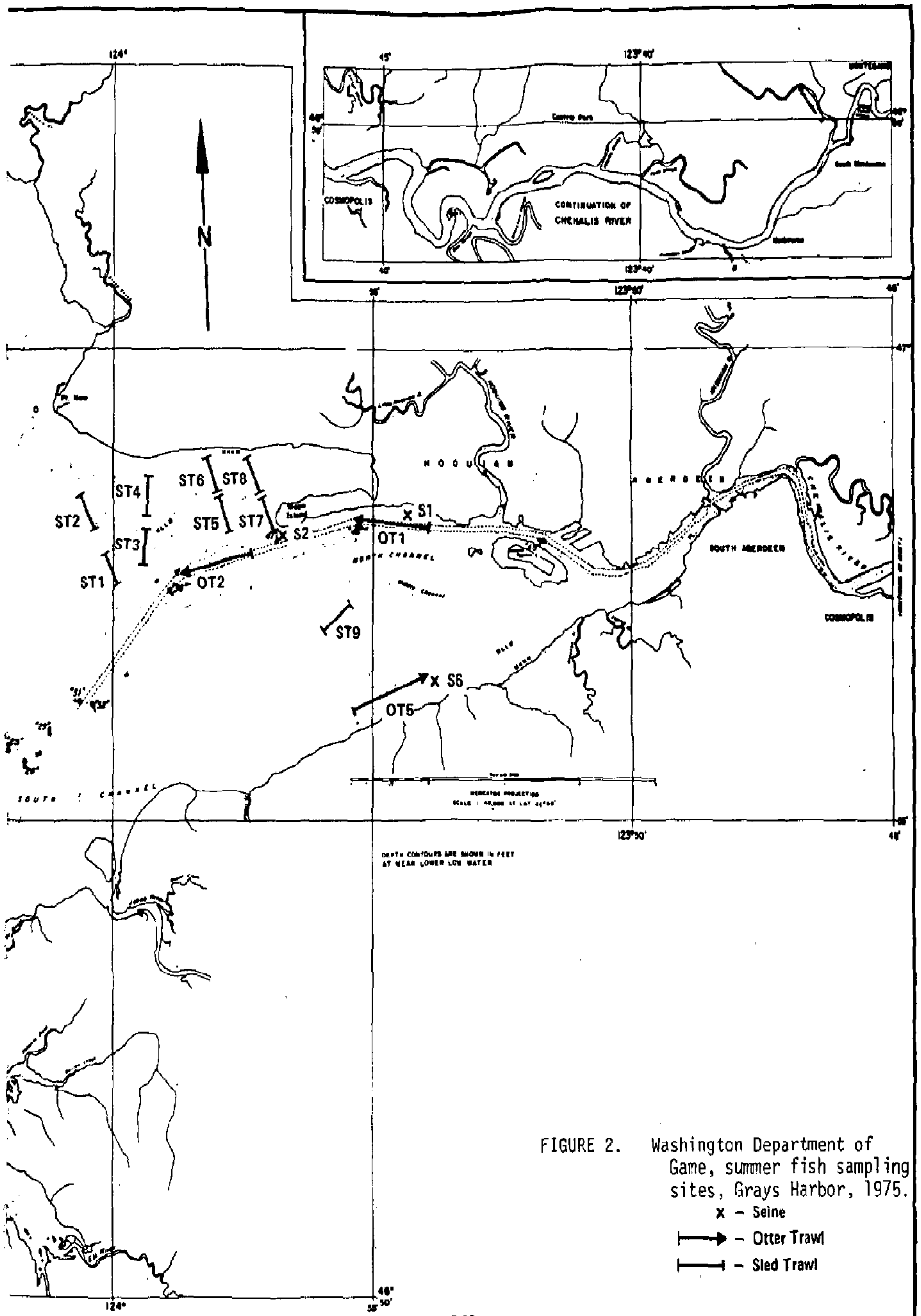

FIGURE 2. Washington Department of Game, summer fish sampling sites, Grays Harbor, 1975.
x – Seine
⟼ – Otter Trawl
├─┤ – Sled Trawl

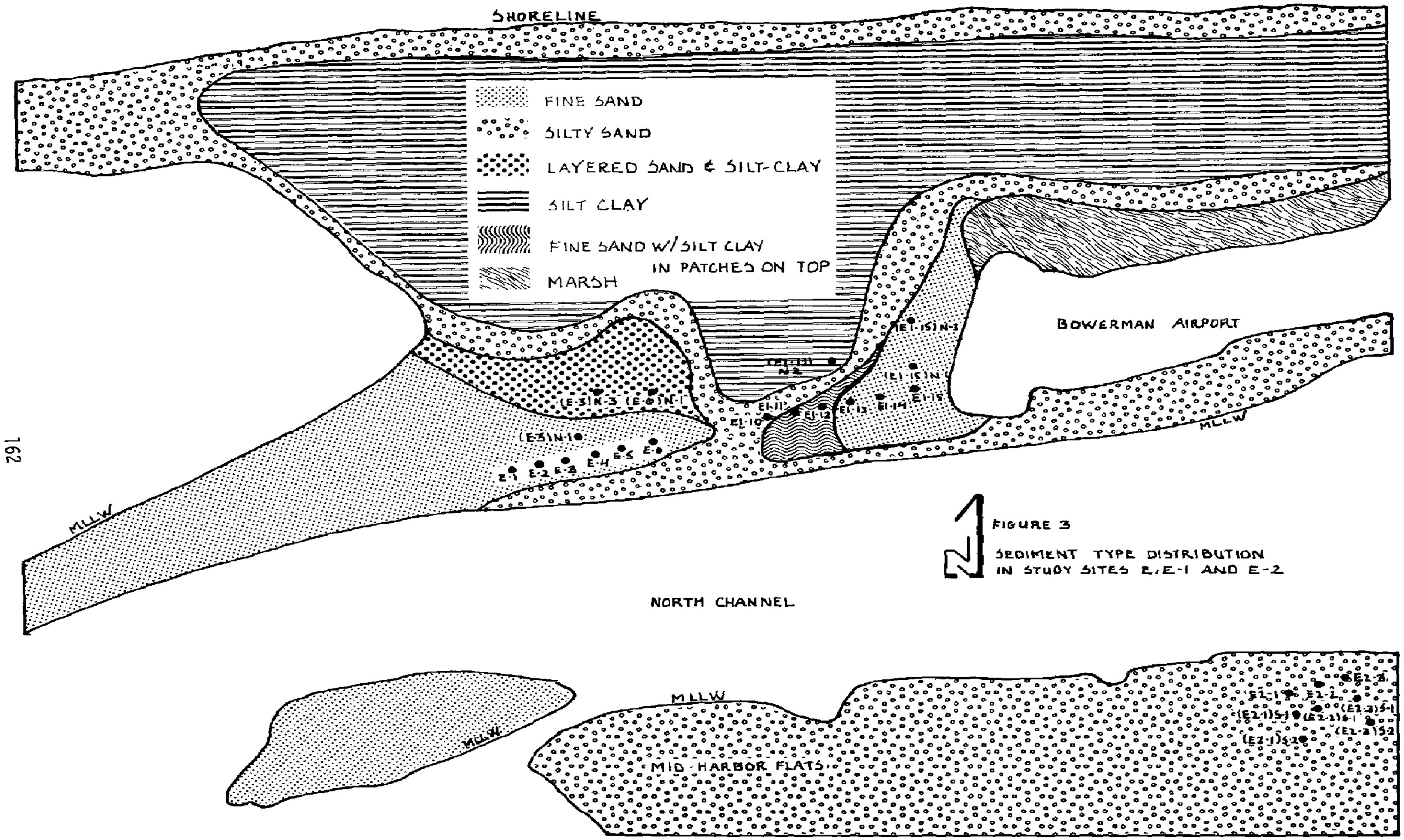

FIGURE 3

SEDIMENT TYPE DISTRIBUTION IN STUDY SITES E, E-1 AND E-2

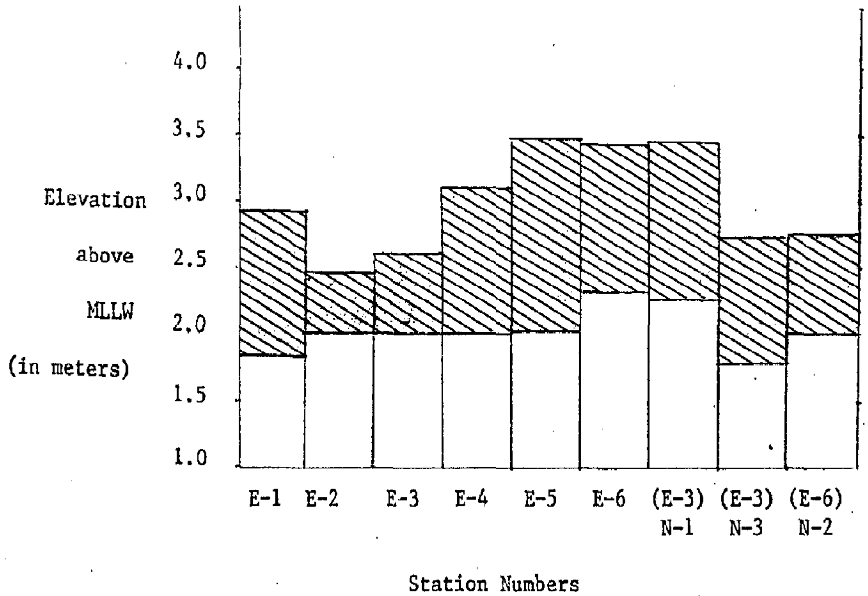

Figure 4. The elevations at nine stations in the unconfined intertidal disposal area (Site E) both before and after the 1975 dredging operation. The shaded region indicates the resultant change in elevation.

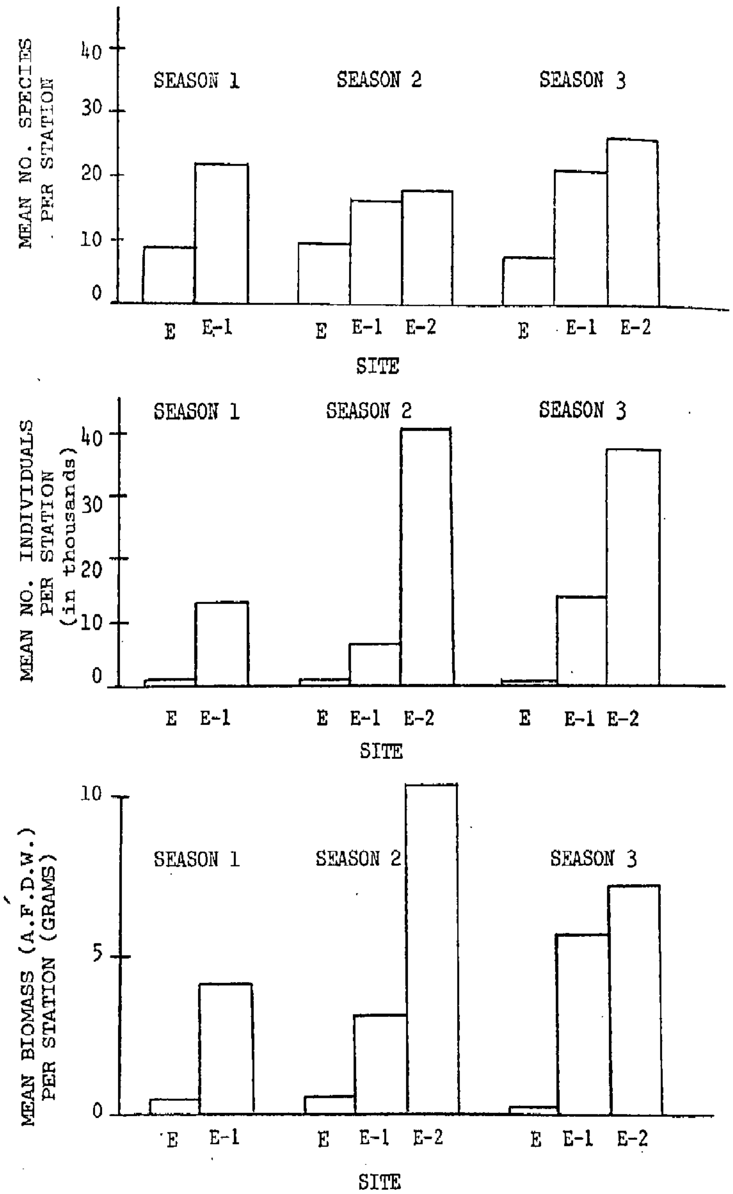

FIGURE 5. Comparison of mean number of species, mean number of individuals, and mean biomass per station in Sites E, E-1, and E-2 in Grays Harbor, Wa., 1974-75.

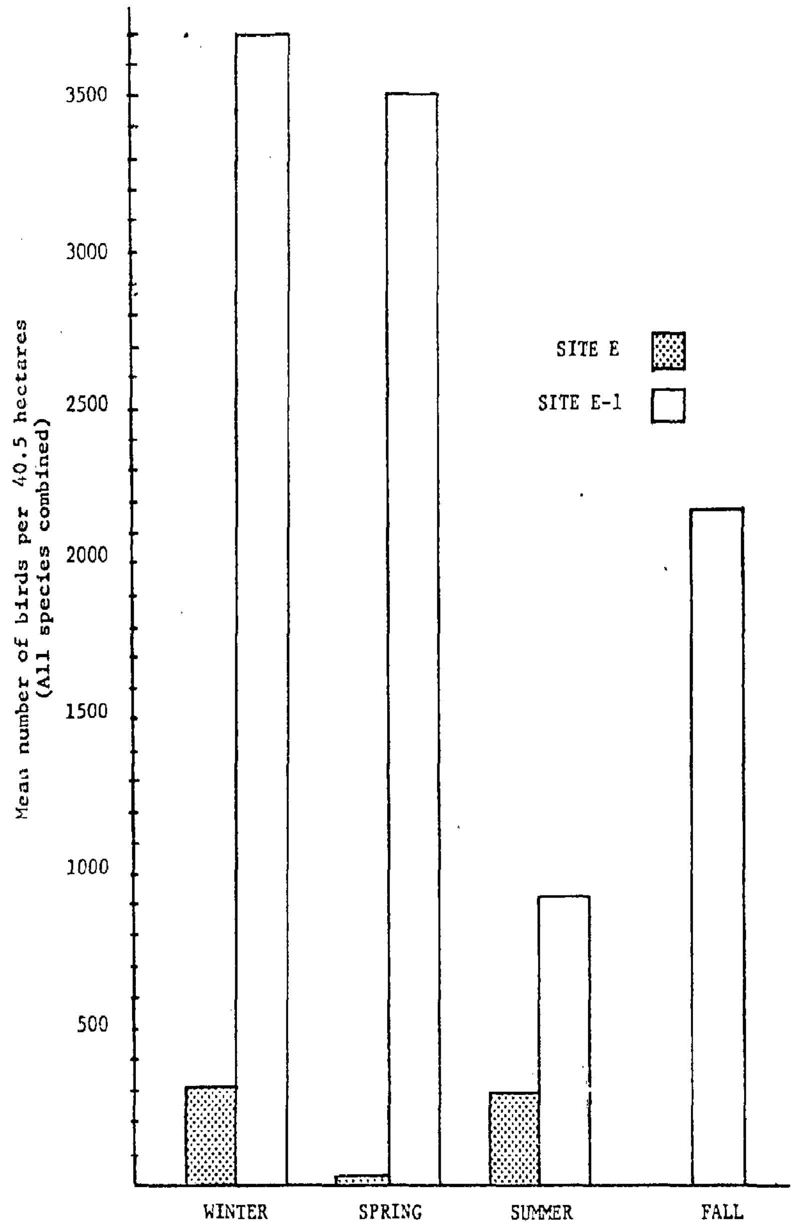

FIGURE 6. Total seasonal densities of birds using tideflats at disposal Site E and contrast Site E-1. (Figure by Jack L. Smith and David R. Mudd.)

The pattern of bird usage of Site E reflected a trend similar to the benthos, although not quite as drastic (Figure 6). Bird utilization of Site E-1 was sixteen times that at Site E. The population of birds was dominated by shorebirds, as the disposal area and contrast site are in a portion of Grays Harbor heavily used by shorebirds. Maximum numbers for the area reached 70,000 during the spring of 1975. Observations of feeding shorebirds at Sites E and E-1 showed a much greater contrast, similar in magnitude to differences observed for benthic invertebrates between the two sites (Figure 7). These benthic organisms provide a food source for the shorebirds. Dunlin were the most numerous shorebird species in the area, comprising 80 percent of the total number of shorebirds. They were most often found to feed at elevations below +2.13 m where benthic populations, especially that of *Corophium stimpsoni*, were highest. Six other species of shorebirds (Western Sandpipers, Long-billed Dowitchers, Red Knots, Black-bellied Plovers, and Lesser and Greater Yellowlegs) also fed at elevations below +2.13 m. Only 4 species fed above +2.13 m in both sites combined. The mean density of feeding shorebirds was one hundred times higher below +2.13 m than above. This relationship correlated well with the food habits work which indicated that Dunlin were feeding heavily on benthic invertebrates with *Corophium stimpsoni* comprising 52.5 percent of the number of food items. It is also likely that Western Sandpipers and Long-billed Dowitchers also utilized *Corophium stimpsoni* as a food resource to a lesser extent.

Site E was often used by birds as a resting area, especially during higher tides when much of the tideflats used for feeding were inundated. This accounts for the densities of birds at Site E being much closer to densities found at Site E-1 when all birds were considered, as opposed to density differences when only feeding shorebirds were considered. Thus an area suitable for resting has replaced a high quality feeding area.

Corophium stimpsoni and other invertebrates abundant at Sites E-1 and E-2 also provide food for many fish species which occur in Grays Harbor, including several commercially important species. Salmon (*Oncorhynchus* spp.), shiner perch (*Cymatogaster aggregata*), English sole (*Parophrys vetulus*), starry flounder (*Platichthys stellatus*), longfin smelt (*Spirinchus thaleichthys*), Pacific staghorn sculpin (*Leptocottus armatus*), threespined stickleback (*Gasterosteus aculeatus*), snake prickleback (*Lumpenus sagitta*), juvenile Pacific tomcod (*Microgadus proximus*), and saddleback gunnels (*Pholis ornata*) are species which feed on *Corophium stimpsoni* in Grays Harbor. Fish sampling in areas around Site E indicated that English sole used that portion of the harbor as a nursery area (Figure 8). This is probably true for other species as well (Lynam, 1972).

These populations were all impacted as a result of disposal of dredged material in the same manner as shorebirds, i.e. through destruction of their food resources. In addition, their predators will also be impacted. These benthic feeding fish and birds are important to piscivorous waterbirds, raptors, marine mammals, other fish and man. Many organisms which ultimately benefit from this food chain do not even occur in Grays Harbor proper.

Even before the 1975 disposal operation, the eelgrass *(Zostera marina)* habitat at much of the Site E area had been destroyed due to the increase in elevation. After disposal in 1975, an estimated minimum of 70.8 ha (175 acres) of eelgrass habitat had been destroyed. Therefore, Widgeon, Pintails, and other species of

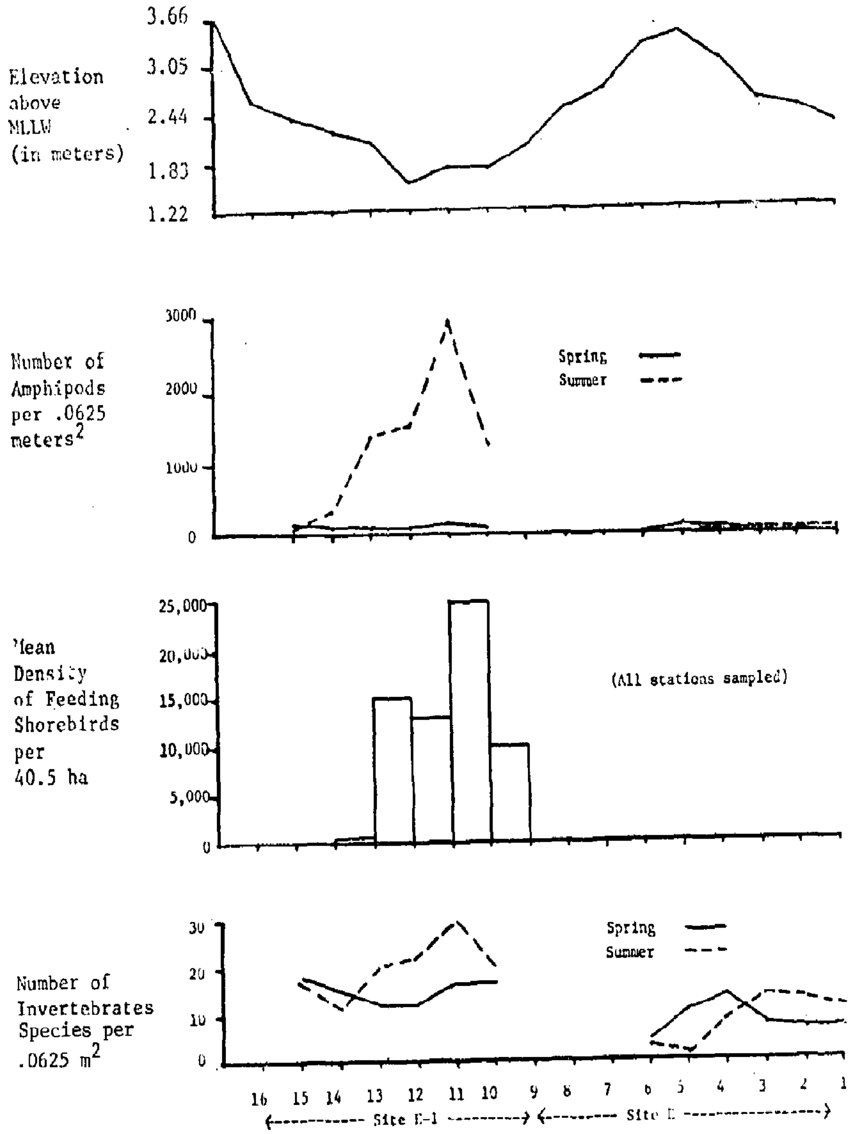

FIGURE 7. Some relationships between elevation at Sites E and and E-1, populations of benthic invertebrates occurring along the transect, and the utilization of the area by feeding shorebirds from April through September, 1975.

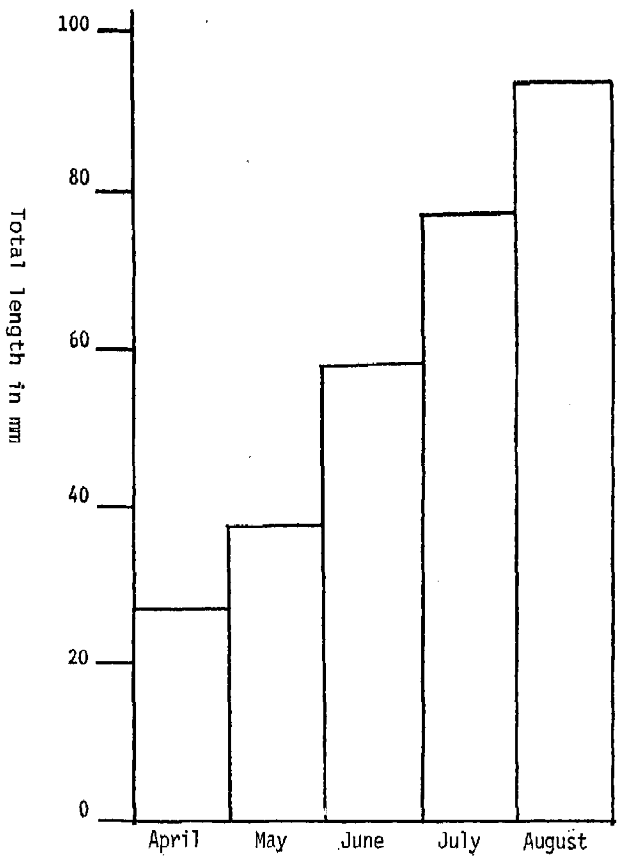

Figure 8. Mean size by month of English sole (*Parophrys vetulus*) taken in Moon Island Flats sled trawls, Grays Harbor, 1975. (Figure by Cliff Bengston and John Brown).

waterfowl and perhaps fish which feed directly on eelgrass were also affected by a loss of food resources. The epiphytic organisms associated with eelgrass, which may sometimes equal 50 percent of the biomass in an eelgrass bed (Thayer, Wolfe and Williams, 1975), and an enriched infauna associated with eelgrass presence (Phillips, 1974; Orth, 1973) were both lost. Thayer, et al.(1975) also stated that a significant portion of eelgrass production is used as detritus outside that area, meaning that the impact of disposal reaches beyond the boundaries of the disposal area. The detritus and/or bacteria associated with it, which are unavailable to benthic organisms, will ultimately have an effect on higher trophic levels including many of the same benthic feeders mentioned earlier. Loss of eelgrass represents a significant loss to estuarine productivity. Phillips (1974) stated that eelgrass has a high rate of production--higher than that of many agricultural crops.

DISCUSSION

As a result of these direct impacts on the biota of Grays Harbor, the Washington Department of Game has recommended that there be no further intertidal disposal of dredged material. At the time of this study, the only legal criteria guiding disposal of dredged material were the Environmental Protection Agency's maximum values regarding water quality parameters. These criteria by themselves were inappropriate, as normal variations in water quality occasionally exceeded certain of these values, without apparent large-scale impact on the biota. They did not take into consideration such gross biological impacts as destruction of habitat or disruption of the food web.

As a result of the Grays Harbor Dredging Effects Study and other studies conducted throughout the country, the regulations regarding disposal of dredged materials were revamped. The basic water quality criteria are now used as guidelines rather than maximum permissible values to determine relative quality of dredged materials in relation to possible adverse impacts on biological communities in or at the disposal site (Ron Lee, EPA, personal communication, 1977). Elutriate tests and bioassays are now considered by EPA to be better indicators of water quality. Both EPA and USACE are required to consider a wide range of potential impacts that should be avoided before a permit for disposal can be issued. Included are impacts on the food chain, alterations or decreases in diversity of species, effects on adjacent areas, and in general, any "activities that significantly disrupt the chemical, physical, and biological integrity of the aquatic ecosystem, of which aquatic biota, the substrate, and the normal fluctuations of water level are integral components" (EPA, 1975:41295). Due to the diversity of potential disposal areas to be considered, it is impossible to state specific criteria which will cover the wide range of possible impacts. The new criteria thus allow for case-by-case reviews of environmental impacts. The criteria are such that additional environmental information regarding baseline biological or water quality data relevant to a potential disposal site can be required. These criteria appear to be superior to the former regulations. However, the result is a set of guidelines that are extremely judgemental and therefore are dependent on the availability of sufficient biological baseline data and thorough study of various potential impacts.

The "state of the art" does not include conclusive evidence as to all potential impacts concerning disposal, especially in cases where dredged materials come from a polluted source. Synergistic effects involving chemical and physical changes in the environment and their effects on biological communities are not well understood and need more study. Baseline information on biological resources is essential and must cover trophic relationships within communities and interactions between communities so as to establish the true extent of possible impacts. This will greatly facilitate all management decisions regarding the shoreline of Washington State.

Habitat creation, most notably island and marsh creation, should be evaluated to determine both detrimental and beneficial effects. Such studies should begin by looking at existing islands created by disposal, such as those in Padilla Bay, Washington, to observe avian and mammalian activity, vegetative colonization, and adjacent benthic and fish communities. Artificial planting of marsh plants on these islands should also be investigated. If any exotic marsh plants are to be used in planting experiments, their interaction with indigenous salt marsh plants must be evaluated. Deep water disposal should be studied as a possible alternative to intertidal disposal. Decisions regarding this alternative should not depend largely on studies done in other parts of the country. An intensive study on the biological impacts should be conducted in Puget Sound waters to provide a sound basis for management decisions.

Long-term management of Puget Sound waters must also include involvement in terrestrial activities which affect the marine environment. Forest and agricultural practices have resulted in large quantities of sediments entering estuaries. This has increased natural sedimentation rates and is largely responsible for the quantities of material that must be dredged. Control of soil erosion at the source will greatly enhance the longevity of our estuarine resources. Recycling of these eroded sediments may be feasible using upland disposal sites and through treatment of the soils to leach out salts.

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Fish	Cliff Bengston John Brown
Benthos	Alan D. Rammer

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CURRENT SHELLFISH PRODUCTION IN PUGET SOUND AND POTENTIAL FOR THE FUTURE RELATED TO PRESENT AND FUTURE INSTITUTIONAL BARRIERS

Ronald E. Westley
Washington Department of Fisheries

An evaluation of the oyster producing potential of Puget Sound reveals that a sustained annual production of up to 6 billion pounds of meat may be possible. Production at this level is based upon using the methods of floating culture developed in Japan in combination with the tremendous fertility and food producing ability of Puget Sound.

Puget Sound currently has a thriving fishery for shellfish, both sport and commercial, and considerable opportunity exists for expansion. Principal species taken are oysters, hardshell clams, soft-shell clams, geoducks, crab, and shrimp. Particularly the harvest aspects of clams have become controversial and legal constraints have been placed on many of these activities. It would appear that in the future these problems may become more wide-spread and affect major aspects of the shellfish industry.

Problems have arisen over interpretation of laws and regulations concerning shellfish harvest (the Shoreline Management Act and the State Environmental Policy Act). Problems are also occurring in reference to the 1899 Rivers and Harbors Act of the Corps of Engineers.

Washington is now an important shellfish producing state, and has the potential for a major increase in the shellfish harvest. The current level of production is as follows:

	Commercial	Sport
Geoducks	5,000,000	?
Clams	2,000,000	4,000,000
Oysters	6,000,000	100,000
Crab	10,000,000	250,000
Shrimp	10,000,000	?

An important aspect for potential increased shellfish production is the unique nature of Puget Sound, resulting from a combination of tide range and the extremely high levels of nutrient. This makes Puget Sound one of the cleanest and most fertile estuaries with extremely high primary productivity levels. Due to basic relationships in converting primary productivity into human food, Molluscan shellfish are vastly more efficient than higher forms of animal life, and it therefore seems certain that serious efforts to increase food production in the Sound will heavily involve Molluscan shellfish (oysters and clams). If food production becomes a high priority activity, and we are willing to commit the needed area and effort, the following harvest levels could be achieved on a sustained basis.

Geoducks	15,000,000 pounds or more
Clams	12,000,000
Oysters	1,000,000,000

Most of the increase would be based on oysters and I do want to stress that while this level of harvest is biologically feasible, it is not now economically feasible and that major changes in demand and economics would have to occur before these levels of harvest would be realistic.

In addition to the biological and economic aspects, problems of a legal nature are becoming an increasingly important factor in continuing or expanding shellfish production in Puget Sound. This is the combined effect of several state and federal laws that have recently been passed or re-interpreted to regulate or control the utilization of water areas. Today, for example, a person entering or wanting to continue in extensive marine farming in Puget Sound must overcome the following:

1. Obtain a permit from the Corps of Engineers under Section 10 of the 1899 Rivers and Harbors Act. Currently as the Corps interprets the law, this is the case for mechanical clam harvest and raft culture of oysters or mussels.

2. Depending upon the outcome of current legal proceedings, a person probably would need a Shoreline Management Permit. This would appear to apply to mechanical clam harvesting and any operation involving raft or floating culture, such as oysters or mussels.

3. If any phase of farming activity comes under the jurisdiction of any state or county agency, that is if it involves a lease, license, or permit, that agency must follow the requirements of the State Environmental Policy Act prior to granting of any license, permit, or lease. Often this requires the preparation of an Environmental Impact Statement.

That any project is subject to careful scrutiny is, of course, good. However, in my opinion from a practical point of view, with the possible exception of the State Environmental Policy Act, the standards of acceptability are somewhat nebulous and it appears possible for the soundest of projects to become bogged down. Under the current system, if someone chooses to challenge a proposal, all possible information on all aspects could be required and even if this could be achieved, there is no assurance of approval. Under this system, the proponent could be in a position to prove a negative which by elementary logic is impossible. However, at present even well intentioned but either poorly informed or careless people can bring almost any project to a complete standstill. Almost anyone can exploit areas where information is less than complete.

Based on previous experiences in trying to protect water quality in the Sound, long before it was a popular cause, I believe that encouraging food productions is of considerable value. First, this can be done as a non-consumptive, non-degrading use of the water. Second, it could furnish needed food for people. Last, since shellfish production can only be carried out in waters of the highest quality, substantial use of Puget Sound for food production establishes a considerable economic justification for maintaining high water quality. It is, therefore, with considerable frustration that I find our current system, intended to protect Puget Sound, can lead to blocking its potential use for food production. Based upon the aforementioned previous experience, I keenly sense the value that the present level of public support has had in efforts to protect this area. There is no question that major strides have been made via the current laws and regulations. However, I think we are overdue for a much needed second step. I believe we now need to ask the question "Management of Puget Sound--for what purpose and for whom?" From a practical point of view, the present situation provides more control than management. Instead of sound rational management in the best interest of all of the citizens of state as is, we are at times trading some past problems for new ones. Blocking uses in certain areas can have the net effect of allocating portions of this common property resource to different interest groups, the so-called "taking issue."

Solving this problem and outlining the action that is needed is far from simple, and my method may not be the best, but it is an approach. In considering the problem I started by trying to list the major potential uses which in my view are transportation, food production, recreation, and waste disposal. While I consider education and advancement of knowledge as valid uses, I do not consider scientific research as such a use by itself. Some of these uses are competing and some are conflicting. However, with careful planning based on adequate knowledge, these conflicts can be minimized in the best interest of all of the citizens of the state, both now and in the future.

I suggest that the first step to be taken is to carefully identify the proper interests that need to be represented in development of a Management Plan for Puget Sound. Second, we need to determine the purposes and objectives of a Management Plan. This must be done in fairly specific detail to minimize conflicts.

Coincidently, I believe a carefully selected panel of very knowledgeable people should be set up both to help in development and implementation of the Management Plan and to serve as a decision making body. I believe that such a panel would require the ability and responsibility to evaluate the information available and that needed in the identified subject areas concerned with management of Puget Sound. The panel would also need to have the proper balance to represent all of the citizens of the state.

Although the legal community would need to be represented, I do not believe that by itself it would be capable of adequately assessing all factors to make the proper decision.

I believe that while the scientific community must be represented, it has not by itself been able to adequately provide solutions.

Provision must be continued to represent local area interests, but we must also reflect the overall interest of the entire state.

I suspect that to achieve this, certain federal and state laws would need to be changed, combined, or eliminated, but we must develop a workable system to eliminate the current problems and allow sound management.

I do not know if my approach is the best solution, others may be better. My main purpose is to point out what I believe to be the problem and to stimulate a solution. I strongly believe that at present we are controlling use of Puget Sound but not managing it.

I do not want to create the wrong impression. I firmly believe in the need to protect and preserve Puget Sound. I believe that major steps and excellent efforts have been made in this regard. However, I see a major problem and I would like to see it solved.

AN ASSESSMENT OF THE EFFECTS OF SUBTIDAL SEWAGE OUTFALLS ON INTERTIDAL MACROFAUNA OF SEVERAL CENTRAL PUGET SOUND BEACHES

John W. Armstrong, Ronald M. Thom, Craig P. Staude, and Kenneth K. Chew
University of Washington

INTRODUCTION

For several years Seattle has been discharging its wastewater into central Puget Sound from several subtidal outfalls (in order of discharge volume--West Point, Alki, Carkeek, and Richmond beach outfalls). Bendiner (1975) has shown through dye studies that the effluent from West Point outfall (the only one studied intensively to date) does reach the intertidal area at West Point beach. This occurrence is further supported by the drogue studies of Ebbesmeyer and Helseth, (1975) which described eddies on the north and south sides of West Point. These eddies increase the amount of time which effluent enriched waters remain in the intertidal and nearshore areas. Previous research in both fresh waters and marine environments indicates that the fauna and flora in areas influenced by municipal sewage outfalls often change dramatically when compared to communities in unaffected areas (Filice, 1959; Jones, 1973; Reish et al., 1975; Otte and Levings, 1975, and Smith and Green, 1976).

In July, 1974, we began a 2-year study of the intertidal macrofaunal communities at 4 beaches adjacent to the sewage outfalls and 1 beach without an outfall, Lincoln Park beach. The intertidal zone was chosen for this study because of its relative ease of access and sampling, its importance in overall marine productivity and its recreational and aesthetic importance to the general public. Furthermore, most intertidal animals lead a sedentary or nearly sedentary life and cannot leave an affected area as motile organisms, such as fish, can. The intertidal organisms, many with relatively long life cycles, integrate and reflect the effects of conditions in their distributions, abundances, growth rates, and community structure.

We have attempted to find significant differences between the faunal communities of these 5 beaches which would indicate the existence of wastewater-related stresses. We have chosen our sampling methods and statistical approach in such a way as to maximize any existing differences between the organisms and communities of the beaches.

MATERIALS AND METHODS

The 5 Seattle area beaches which were studied (Figure 1) have been previously described (Armstrong, 1976).

The sewage treatment plant at West Point discharges an average of 122 million gallons per day (mgd) while the treatment plants at the other beaches discharge considerably less (Alki--8.3 mgd, Carkeek--3.7 mgd, and Richmond 1.7 mgd). Lincoln Park beach, our control, has no sewage treatment plant outfall.

The beaches were sampled quarterly from July, 1974 through April, 1976. Quarterly sampling was conducted to collect species whose intertidal occurrence is of a seasonal nature. Several transect lines were established perpendicular to the water at each beach. Systematic sampling was conducted at 0, 0.9 (3 ft.) and 1.8 (6 ft.) meters above the mean lower low water level. Other areas of each beach were intensively searched for additional species.

The systematic sampling consisted of examining 2 .25 m^2 areas at each of the above tidal levels in sandy and mixed sediments at each beach. "Mixed-sediments" refers to mixtures of sand and various gravels (up to about 60 mm in diameter) and cobbles (from about 60 to 260 mm in diameter). The macroscopically evident epifauna within each .25 m^2 was subsampled from 4 random 100 cm^2 areas, identified and counted. Two sediment samples were taken from within each .25 m^2 with a cylindrical coring device (31.2 cm^2 in cross-sectional area and 15 cm long). Each .25 m^2 was then dug to a depth of approximately 25 cm and live-screened through a 6 mm screen on the beach. The sediment core samples were preserved and stained in a 10% formaline and Rose Bengal solution for at least 24 hours and then washed through a 1.0 mm screen in the laboratory. After both of the above screening procedures, all animals were removed from the screens, identified and counted.

Biomass was recorded for the 6 mm screen preserved bivalve and polychaete samples. Polychaetes were blotted dry and weighed. Tubaceous species were removed from their tubes before weighing. Bivalves were weighed in the shell after all liquid was drained off.

Species diversities were calculated for individual taxa (polychaetes, bivalves and amphipods) and compared within and between beaches by a parametric one-way analysis of variance. The species diversity indices calculated were those of Brillouin (1956), Shannon-Weaver (1949) and Simpson (1949) as suggested by McErlean et al., (1972) and Green (1975). Hurlburt (1971) species-area curves were also calculated for the above taxa and confidence limits were placed in these curves (Smith and Grassle, 1977).

Similarities between the fauna of different sampling stations were compared with classification techniques. The Bray and Curtis (1957) similarity coefficient was calculated for the fauna collected by each sampling method at each station. The abundances of each species at each station were transformed by taking the cube root of the abundance value. This transformation rises the contribution of minor species which may be ecologically discriminating (Smartt, et al., 1976). Station similarity values were compared with the group-average sorting strategy and resulting "clusters" of stations were graphed in dendrograms.

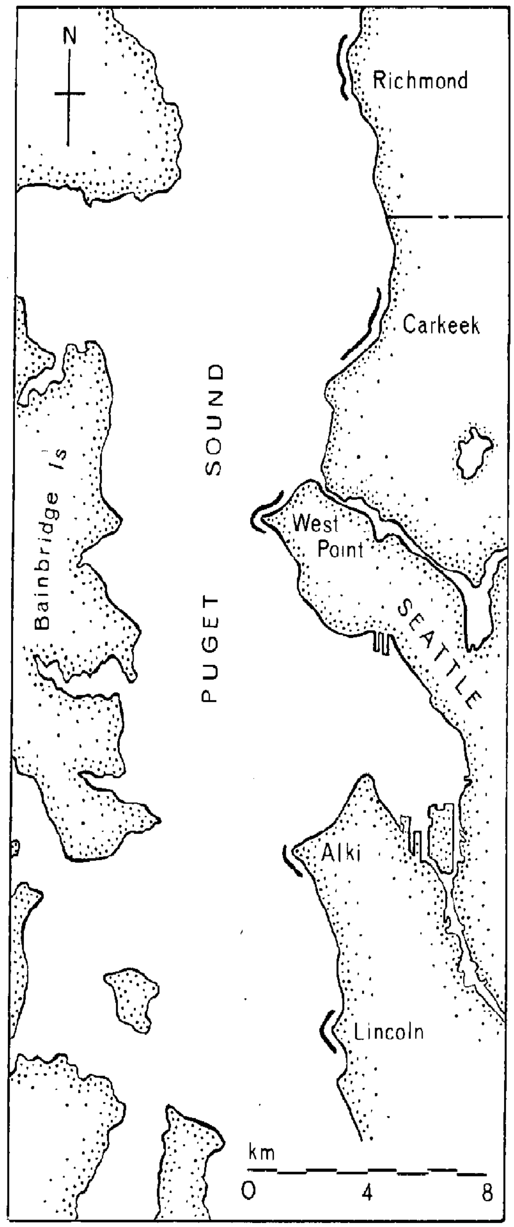

Figure 1. Map of central Puget Sound, showing the positions of the five study beaches in relation to Seattle, Washington. The actual areas sampled are indicated by heavy lines.

RESULTS

At least 301 species of macrofauna (some groups such as flatworms, oligochaetes, and nematodes are considered as single entities due to taxonomic difficulties) were collected during the 2-year course of this study. These species were collected by systematic sampling and intensive searching on each beach. Approximately 2% of the species collected are new to science and we are presently describing 4 of them.

In Table 1, the species list is condensed into several taxa so that qualitative comparisons may be made between beaches. West Point (the beach adjacent to the largest volume wastewater discharge) and Lincoln Park (the control beach) have the most species. Richmond, Alki, and Carkeek beaches have 10-15% less species present but the relative abundance of each taxa is the same for all 5 beaches (tested by Kendall's coefficient of concordance, P 0.005). West Point and Lincoln Park beaches also have more species found only at their sites (unique) than the other 3 beaches but this is probably due to the more heterogeneous habitat and subsequent increased variety of niches at West Point and Lincoln beaches.

The total number of species collected per cobble transect (at tide heights 0, +0.9, and +1.8 m) was compared between transects (2 per beach) and beaches (Table 2). All transects sampled will be identified by the first letter of the beach and the transect number. The number of species per transect was tested for seasonal differences at the 5 beaches (a total of 10 transects) by Friedman's nonparametric two way analysis of variance and multiple comparisons tests. The tests indicate a seasonal difference in the number of species present, with October, 1976 having significantly more species than July, 1976 and April 1977 (P .05).

On each transect the fauna were quantitatively sampled at the 3 previously mentioned tide heights. While all sampling methods were employed at each tide height, only selected data will be presented here.

The dominant (by abundance) species collected with the 6-mm screens in the cobble substrate (0 and +.9 m tide heights) were compared between beaches. Only the data from July, 1975 through April, 1976 are presented. The 7 most abundant polychates (Table 3) contributed 97% to the total number of polychaetes collected. Due to great within-beach variability, the ranks and abundances of the fauna in Tables 3-7 are not presented for statistical comparisons. These tables summarize the species collected in 2 mixed-sediment habitats at each beach.

Differences between the beaches include the occurrence of large numbers of capitellids. Carkeek, Lincoln, and Richmond beaches had the greatest numbers of capitellids (grouped as a family, but excluding *Capitella capitata* due to identification inconsistencies) and West Point, Lincoln, and Alki beaches had the great numbers of *Owenia fusiformis*. *Lumbrineris zonata* occurred in large numbers only at Richmond beach. West Point and Lincoln Park had the most individual polychaetes while Alki, Carkeek, and Richmond beaches all had 25 to 30% less.

The 6 most abundant infaunal bivalves accounted for 99% of all infaunal bivalves (Table 4). West Point and Carkeek were both characterized by a reduced number of *Protothaca staminea* while Alki had a large number of this species. Carkeek Beach

Table 1. The organisms occurring on the five study beaches by major taxa.

	Richmond	Carkeek	West Point	Alki	Lincoln
#species/beach	206	195	230	203	230
#species unique to each beach	8	8	16	5	20
Coelenterates	6	6	5	7	7
Annelids	75	64	73	64	73
Molluscs	44	43	51	51	48
Bivalves	20	20	20	20	18
Gastropods	13	13	15	14	13
Nudibranchs	4	5	9	8	8
Arthropods	59	53	73	65	67
Isopods	9	8	11	10	10
Gammarid Amphipods	19	19	26	24	26
Decapods	19	15	23	19	21
Echinoderms	5	7	8	9	11
Fish	4	5	7	5	8

Table 2. Number of species collected per cobble transect by standard sampling methods. A = Alki, C = Carkeek, L = Lincoln, R = Richmond, W = West Point.

Transect	Number of Species Collected			
	July, 1975	October, 1975	January, 1976	April, 1976
A 9	49	78	54	49
A 10	56	80	66	63
C 7	42	52	42	42
C 11	50	66	61	55
L 1	59	79	77	60
L 17	57	71	62	64
R 13	57	73	62	48
R 15	46	68	47	45
W 10	54	77	71	71
W 19	51	66	41	46

Table 3. Ranking of the most abundant polychaetes collected in cobble areas with a 6 mm screen. Includes 0 and +.09m tide height samples.

Ranks per beach with numbers collected in parentheses

	Alki	Carkeek	Lincoln	Richmond	West Point
Capitellidae	3 (414)	1 (1112)	1 (1094)	1 (793)	3 (319)
Owenia fusiformis	1 (865)	2 (573)	2 (918)	3 (226)	1 (1493)
Hemipodus borealis	2 (565)	3 (280)	3 (446)	5 (98)	4 (265)
Glycinde picta	5 (65)	4 (144)	4 (68)	6 (80)	5 (167)
Plantynereis bicanaliculata	4 (241)	5 (29)	6 (64)	4 (167)	2 (403)
Lumbrineris zonata	6.5 (4)	- (0)	- (0)	2 (365)	6.5 (31)
Glycera capitata	6.5 (4)	6 (2)	5 (66)	7 (90)	6.5 (31)
Total	(2158)	(2140)	(2656)	(1819)	(2709)

Table 4. Rankings of the most abundant infaunal bivalves collected in cobble areas with a 6-mm screen. Includes 0 and +0.9-m tide height samples.

Ranks per beach with number collected im parentheses

	ALKI	CARKEEK	LINCOLN	RICHMOND	WEST POINT
Macoma inquinata	2 (125)	1 (712)	2 (219)	1 (447)	1 (383)
Prototheca staminea	1 (603)	3 (17)	1 (314)	2 (321)	4 (45)
Saxidomus giganteus	3 (121)	2 (127)	3 (165)	3 (249)	2 (74)
Tresus capax	4 (45)	6 (1)	5 (14)	4 (41)	3 (53)
Clinocardium nuttallii	5 (19)	4 (12)	4 (19)	5 (29)	5 (33)
Tellina buttoni	6 (2)	5 (8)	6 (2)	6 (3)	6 (6)
Total	(915)	(877)	(733)	(1090)	(594)

Table 5. Rankings of the five most abundant infaunal bivalves by biomass. All specimens collected were retained in a 6 mm screen. Includes 0 and +0.9-m tide height samples.

Ranks by beach with biomass collected (grams) in parentheses

	ALKI	CARKEEK	LINCOLN	RICHMOND	WEST POINT
Saxidomus giganteus	2 (134)	2 (62)	1 (306)	1 (345)	1 (190)
Prototheca staminea	1 (145)	3 (28)	2 (243)	2 (119)	4 (27)
Macoma inquinata	3 (39)	1 (310)	3 (83)	3 (72)	2 (129)
Tresus capax	4 (13)	5 (1)	4 (9)	4 (61)	3 (90)
Clinocardium nuttallii	5 (6)	4 (24)	5 (2)	5 (14)	5 (23)
Total	(337)	(425)	(643)	(611)	(459)

Table 6. Rankings of the most abundant polychaetes collected in cobble areas with a 1.0-mm screen. Includes only 0 tide height samples.

Ranks per beach with numbers collected in parentheses

	ALKI	CARKEEK	LINCOLN	RICHMOND	WEST POINT
Mediomastus capensis	8 (10)	2 (22)	1 (210)	1 (82)	1 (215)
Owenia fusiformis	2 (39)	11 (1)	2 (143)	6 (20)	2 (79)
Armandia brevis	3 (38)	4 (11)	3 (81)	2 (54)	5 (32)
Notomastus sp.	10.5 (1)	5.5(9)	5 (41)	3 (48)	4 (54)
Malacoceros glutaeus	5 (25)	1 (37)	6 (38)	8 (16)	9 (10)
Platynereis bicanaliculata	4 (36)	9.5(4)	10 (7)	7 (19)	3 (62)
Micropodarke dubia	1 (92)	8 (5)	4 (52)	4 (44)	7 (26)
Pholoe minuta	10.5(1)	3 (17)	7 (29)	10 (7)	10 (4)
Glycinde picta	6 (21)	5.5(9)	8 (17)	5 (36)	6 (28)
Hemipodus borealis	9 (8)	7 (8)	9 (16)	9 (12)	11 (2)
Capitella capitata	7 (11)	9.5(4)	11 (2)	11 (1)	8 (11)
Total	(282)	(127)	(636)	(339)	(523)

Table 7. Rankings of the most abundant surface animals collected in cobble areas. Includes only 0 tide height samples.

Ranks per beach with numbers collected in parentheses.

	ALKI	CARKEEK	LINCOLN	RICHMOND	WEST POINT
Balanus crenatus & Balanus glandula	1 (614)	1 (209)	1 (2323)	1 (1587)	1 (1010)
Lacuna sp.	4 (216)	2 (152)	2 (815)	2 (1015)	2 (834)
Flabelligerid isopods	2 (324)	3 (77)	6 (52)	7 (82)	3 (183)
Collisella strigatella	3 (275)	7 (9)	3 (243)	5 (191)	6 (64)
Mytilus edulis	5 (191)	5 (50)	8 (25)	3 (318)	5 (117)
Caprella laeviuscula	7 (53)	4 (72)	12 (6)	6 (159)	11 (23)
Platynereis bicanaliculata	9.5 (40)	6 (19)	11 (8)	4 (216)	4 (124)
Hyale frequens	8 (50)	- (0)	4 (254)	11 (2)	9 (12)
Allorchestes angustus	6 (115)	8 (5)	5 (86)	-- 0	8 (32)
Ampithoe simulans	9.5 (40)	9 (3)	7 (46)	9.5(6)	7 (54)
Idotea wosnesenskii	11 (17)	11 (1)	9 (23)	9.5(6)	12 (11)
Pontogeneia cf. ivanovi	12 (9)	10 (2)	10 (13)	8 (14)	10 (22)
Total	(1944)	(599)	(3894)	(3596)	(2486)

had the greatest number of *Macoma inquinata* and the lowest number of *Tresus capax*. Richmond and Alki beaches had the greatest number of infaunal bivalves while West Point and Lincoln Park had the lowest number.

The 5 most abundant infaunal bivalves were also ranked at each beach by biomass (Table 5). *Saxidomus giganteus*, *Prototheca staminea* and *Macoma inquinata* contributed the majority of the infaunal biovalve biomass. *Tresus capax* was also an important contributor at West Point and Richmond beaches. Lincoln Park and Richmond had the greatest bivalve biomass and Alki had the least.

The 11 most abundant polychaetes collected from July, 1975 through April, 1976 at the zero tide height cobble sites (2 transects per beach) by our 1.0-mm screen sampling technique are ranked in Table 6. These 11 species make up 93% of all polychaetes collected by this method at the cobble sites. *Mediomastus capensis* and *Owenia fusiformis* were generally the 2 most abundant polychaetes although at Alki, *Micropodarke dubia* was the most abundant and *Malacoceros glutaeus* was the most abundant at Carkeek. As with the 6-mm screen samples, Lincoln and West Point have the greatest number of individuals.

The 12 most abundant surface invertebrates collected at the zero tide height cobble sites were ranked by beach in Table 7. These invertebrates were collected during October, 1974 and from April, 1975 through April, 1976. These organisms make up 97% of the number of surface animals collected. The barnacles *Balanus glandula* and *Balanus crenatus* dominate the epifauna at all beaches while *Lacuna* sp. (a snail) is usually second in abundance (due to its presence in high numbers in the October samples). Lincoln and Richmond beaches have the most surface invertebrates and Carkeek has the least.

The 5 beaches were examined for significant differences in total polychaete and infaunal bivalve biomass by a series of "t" tests. At the zero tide level, Alki had a significantly lower polychaete biomass per unit area than Richmond beaches (P 0.05). At the +0.9-m tide level, Alki has a significantly greater polychaete biomass than West Point beach (P 0.05). None of the other beach comparisons of polychaete biomass were significantly different.

Species diversity values were calculated for all of the polychaetes and bivalves collected at zero tide height with the 6-mm screen and for all polychaetes sampled at zero tide height with the 1.0-mm screen. All samples at a given cobble transect and tide height were pooled for each sampling period (2 6-mm screen samples were pooled and 4 1.0-mm screen samples were pooled). Using the species diversity obtained at 2 cobble transects per beach during 1 sampling period as 2 samples of each beaches "cobble diversity," a one-way analysis of variance was computed for the 5 beaches. This test was performed on data collected from October, 1975 and January, 1976 using each of the previously listed species diversity indices. The variance of the species diversity values was found to be greater "within" each of the 5 beaches than between the beaches for each tide height and each taxa (P 0.05).

The Hurlbert species-area curves for the combined amphipods collected in both the surface and core samples in October, 1976 at the zero tide height cobble sites are illustrated in Figure 2. Although the 95% confidence limits (Smith and Grassle, 1977) are not included in Figure 2, they indicate that sites A9, L17,

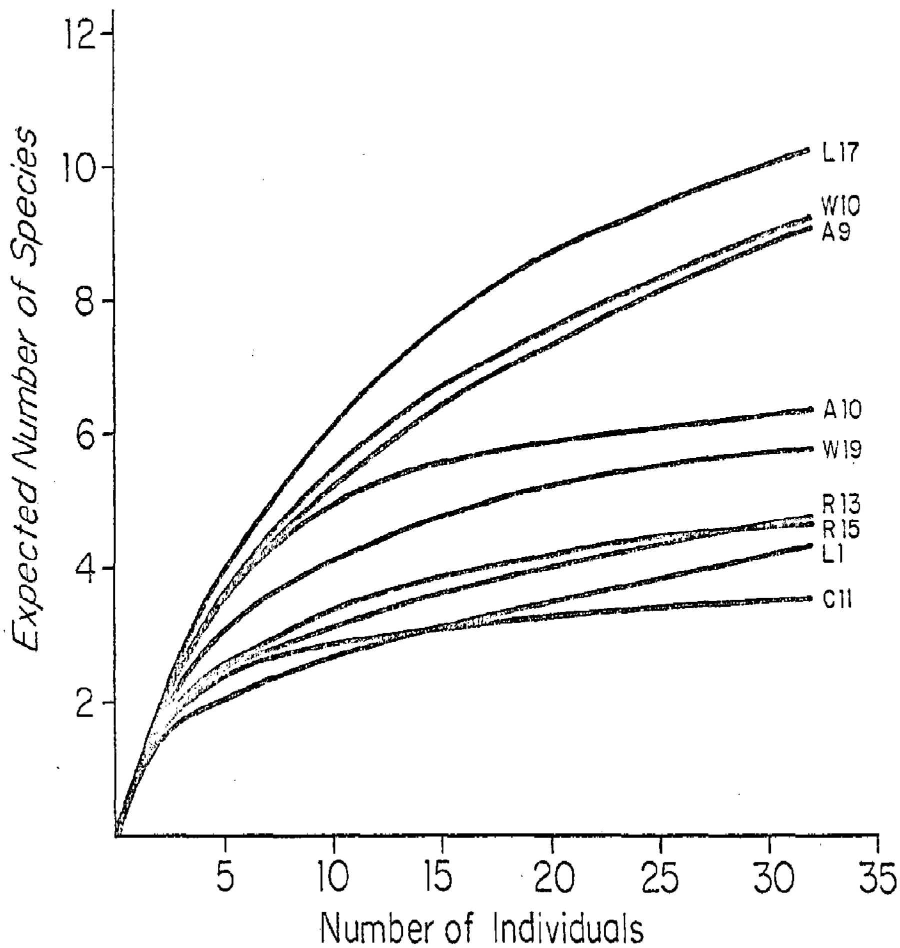

Figure 2. Species-area curves for gammarid amphipods collected in surface and 1.0 mm screen samples at the 0 tide height cobble sites. A=Alki, C=Carkeek, L=Lincoln, R=Richmond, and W=West Point. The numbers represent specific transects.

and W10 are not significantly different from each other but are different from the other homogeneous group (C11, L1, R13, R15, and W19). Additionally, A10 and W19 are not significantly different from each other.

Species-area curves are also presented for all species collected (October, 1975, through April, 1976) in the 1.0 mm-screen at sandy sites (Figure 3). None of these curves are significantly different from one another (P 0.05). Neither Lincoln or Alki beaches have any fine-sand sites and therefore can not be compared in this analysis.

Another method of comparing the similarity of the abundances and types of organisms in different samples or areas is by means of similarity coefficients (Clifford and Stephenson, 1975). The Bray-Curtis similarity coefficient was calculated for all sampling sites and each method of collection. These coefficients were then subjected to classification separately by tide height. The resultant dendrograms for the zero tide height samples are presented in Figures 4 to 7.

The similarities of the sites as determined from the 1.0 mm screen samples (Figure 4) indicates 3 groups or clusters of stations with internal similarities greater than 55%. As seen in Figure 4, the 5 beaches are intermingled in these groups and neither the sampling stations from Lincoln or West Point beaches stand apart. The stations which are not tightly grouped (R22, L11, R3, and #16) had very few animals and merely "chain" onto the group which had similar species present. The significance of the 3 groups will be examined in the discussion.

The dendrogram for the 6-mm screen and surface samples (Figures 5 and 6) also shows a high degree of similarity between certain sites, with the 6-mm screen sites grouping in much the same manner as the 1.0-mm screen sites. A low number of surface sample sites were analyzed because at the zero tide height many sites had no surface animals (this was related to substrate and stability and will be discussed later).

The distribution of the biomass of different species of infaunal bivalves at the 5 beaches was also subjected to cluster analysis (Figure 7). Groups 1 and 2 contain most of the same sites which clustered together in the 1.0 mm and 6 mm screen sample dendrograms.

DISCUSSION

The physical-chemical data available to us do not indicate great or consistent differences in the intertidal areas of the 5 beaches. Heavy metals concentrations appear to be somewhat higher in some invertebrates and algae at West Point (Olsen, 1976), but we do not have any information on whether or not the concentrations present should be expected to affect the growth, reproduction, or survival of the vast majority of the potential residents of the West Point beach. Due to the lack of bioassy information on nearly all the species present, the species composition, as well as the abundance of the more common species, must be compared between beaches to see if the species and communities present are similar.

The species composition at the beaches adjacent to the sewage outfalls may conceivably be affected by either toxic or growth stimulating components of the

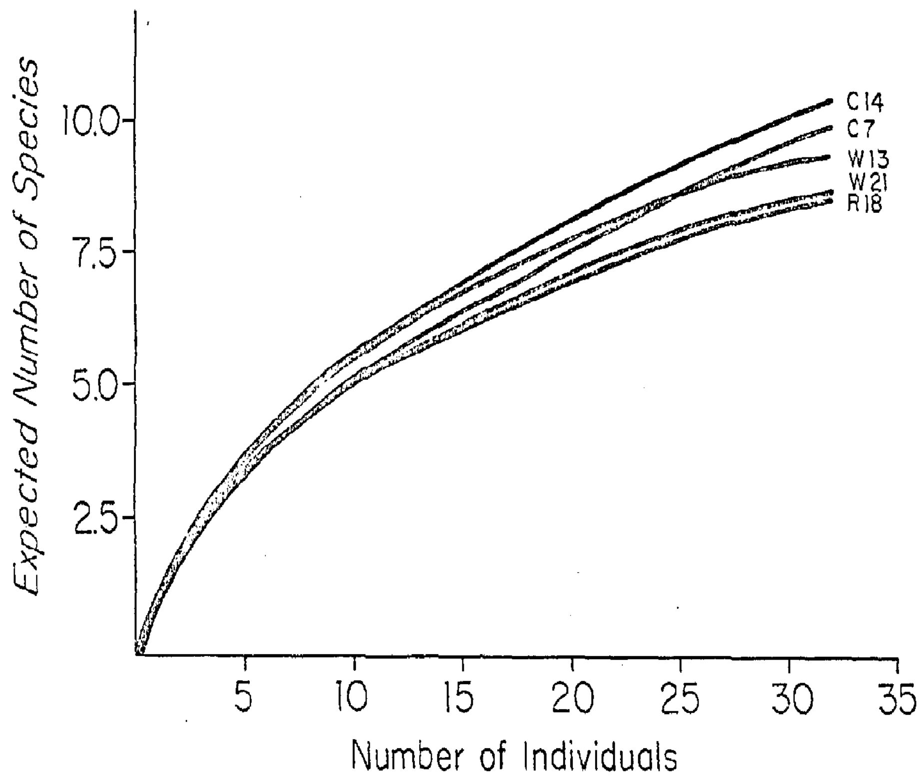

Figure 3. Species-area curves for all invertebrates collected in the 1.0 mm screens at the 0 tide ehight fine-sand sites. C=Carkeek, R=Richmond, and W=West Point. The numbers represent specific transects.

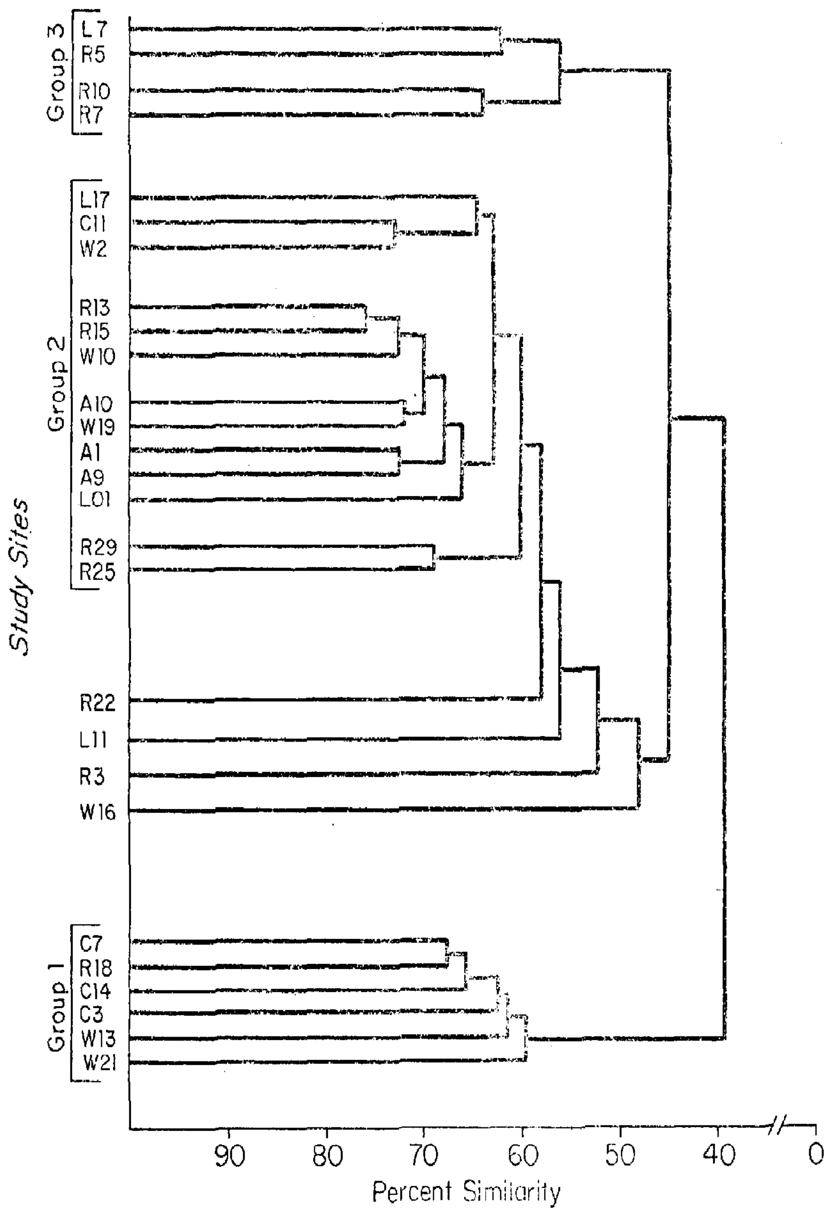

Figure 4. Dendrogram showing relationships between all 0 tide height sites based on the 1.0 mm screen samples. A=Alki, C=Carkeek, L=Lincoln, R=Richmond, and W=West Point. The numbers represent specific transects. Similar sites have been designated as groups.

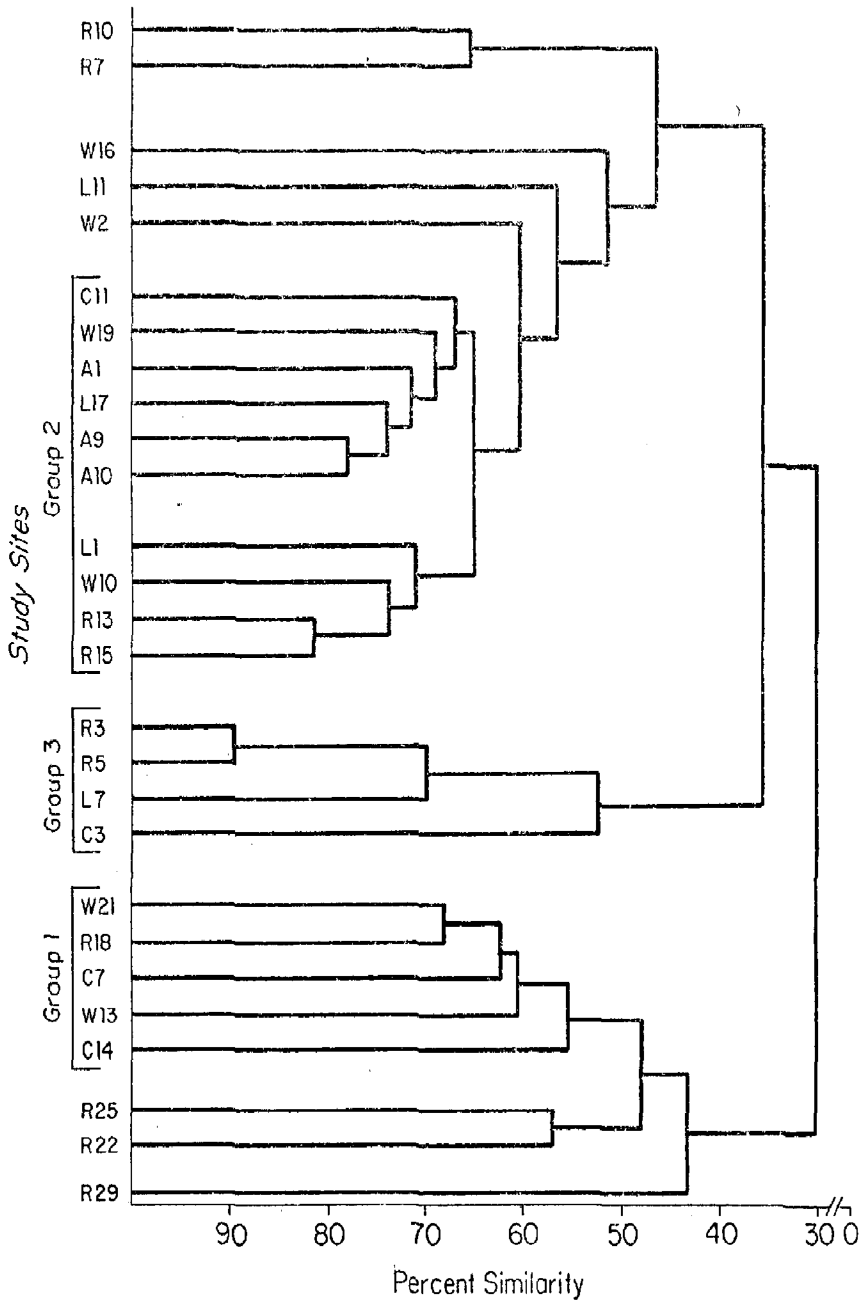

Figure 5. Dendrogram showing relationships between all 0 tide height sites based on the 6.0 mm screen samples. A=Alki, C=Carkeek, L=Lincoln, R=Richmond, and W=West Point. The numbers represent specific transects. Similar sites have been designated as groups.

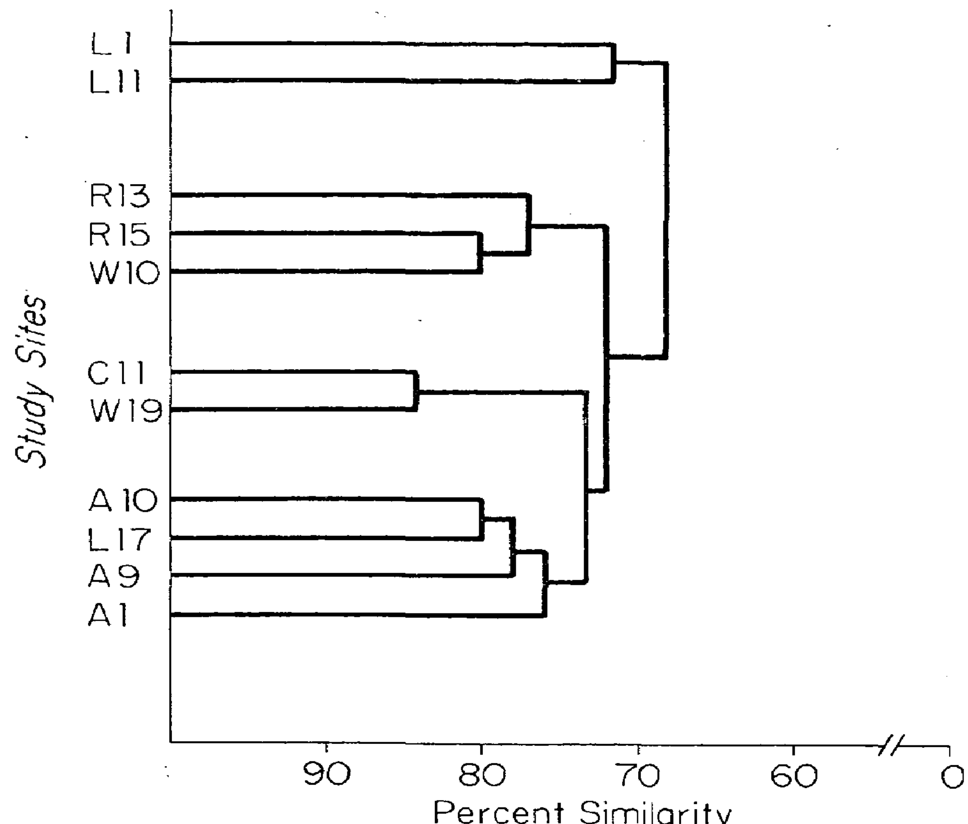

Figure 6. Dendrogram showing relationships between all cobble 0 tide height sites based on the surface invertebrates. A=Alki, C=Carkeek, L=Lincoln, R=Richmond, and W=West Point. The numbers represent specific transects.

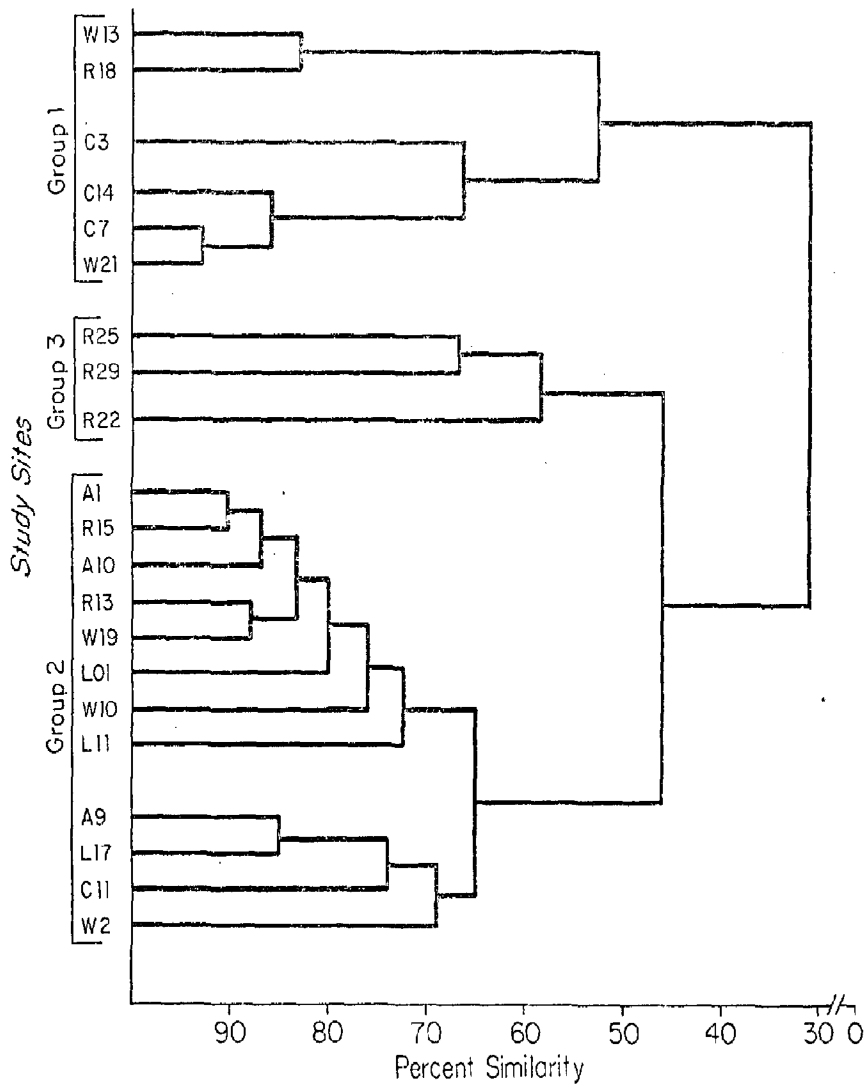

Figure 7. Dendrogram showing relationships between the 0 tide height sites based on the infaunal bivalve biomass collected in the 6 mm screen samples. A=Alki, C=Carkeek, L=Lincoln, R=Richmond, and W=West Point. The numbers represent specific transects. Similar sites have been designated as groups.

wastewater. If the concentration of the effluent reaching the intertidal zone is high enough to stress the fauna there, previous research indicates that some species will be favored at the expense of others (Jones, 1973; Littler and Murray, 1975; and Southern California Coastal Water Research Project, 1975). An examination of the species collected during this study indicates no exclusion of any particular group of species from any one beach. West Point and Lincoln beaches have the most species present. Several researchers have further shown that polluted areas may be dominated by certain animal taxa (Stirn et al., 1973; Otte and Levings, 1975; and Rosenberg, 1976). The relative abundance of various taxa over the 5 study beaches (Table 1) indicates that no one taxa is present in a disproportionate number at any beach.

For our quantitative analysis, the sampling stations were restricted to specific tide heights (0, +0.9, and +1.8 m) to reduce variability between sites which is related to natural intertidal zonation. We further restricted the comparisons to sites or transects of similar substrata (sand or cobble with mixed sediments) with the exception of the site-similarity analysis. When 10 similar cobble transects were compared (Table 2) only 1 species-poor transect (C7) differed significantly from 3 homogeneous species-rich transects (L1, A10, and W10). This result was not surprising because C7 is the only one of the 10 cobble transects considered with a homogeneous sand versus a cobble and mixed-sediment substrate at the zero tide height sampling site. Due to the reduced number of niches in homogeneous sand habitats, we would expect less species at transect C7.

The rankings of the most abundant polychaetes collected in our 6 mm screens (Table 3) includes only 1 species (*Owenia fusiformis*) which has been implicated as a pollution tolerant species (Rosenberg, 1975). However, this species has been reported to exist in very dense beds in clean waters off southern California (Fager, 1964). Since we find *O. fusiformis* in moderate numbers at beaches with and without sewage outfalls, we do not feel it reflects a stressed environment on our study beaches. The abundances of most of these species appear substrate related. *Lumbrineris zonata* occurs in large numbers only at Richmond beach for unknown reasons.

Of the 6 numerous infaunal bivalves collected with the above polychaetes (Table 4), *Protothaca staminea* occurred in low numbers at Carkeek and West Point beaches. We feel this is probably related to substrate instability at the sampled locations at these beaches. We have observed major substrate movement in some areas. *P. staminea* have short siphons and may be subject to smothering in unstable areas. *Macoma inquinata*, a small, flat clam with long siphons, is very dominant at Carkeek and West Point and may be able to withstand substrate changes with *P. staminea* can not tolerate. Furthermore, established beds of a similar Macoma, *M. nasuta*, have been shown to outcompete *Protothaca staminea* in fine sediment areas by consuming the settling larvae of *P. staminea* (Hylleberg and Gallucci, 1975).

The overall clam biomass at each beach (Table 5) reflects the numbers of each species at each beach and the maximum weight which each species may attain. For example, a larger clam such as *Saxidomus giganteus* contributes a greater portion to the biomass at all beaches than it contributes to the numbers of bivalves present. The average weight (and also size) of *P. staminea* was least at Alki beach, as was the overall clam biomass, and may be due to intensive sport digging for clams at Alki. West Point had the greatest biomass of *Tresus capax* (due to few large individuals).

The ranks and abundances of the 1.0 mm screen polychaetes (Table 6) probably reflects substrate preference differences for the various species. Once again, too little is know of the life histories and requirements of these species to relate them to the presence or absence of stressful conditions, whether natural or man-induced. Alki and Carkeek have the fewest organisms and this may be explained by the generally sandy nature of these beaches at the zero tide level.

The surface animals (Table 7) are substrate limited. The majority of these species hide on or under cobble or algae. A Spearman's rank correlation coefficient was calculated in an attempt to correlate both the number of individuals and the number of species with the size and abundance of cobble at each zero tide height station.

A significant ($P < 0.05$) correlation exists between both the numbers of individuals and the number of species with the size and abundance of cobble in an area. Therefore, Alki and Carkeek, with fewer cobble at the 0 tide height, were expected to have a smaller number of surface individuals than the other more cobble-strewn sampling sites. These conclusions agree with those of Kohn and Leviten (1976) and Menge and Sutherland (1976).

As very little is known of the tolerances of the species occurring on the 5 study beaches, species rank comparisons between these beaches may or may not indicate significant trends which reflect wastewater influence upon the intertidal zone. Furthermore, although we chose sites which appeared similar, within-beach variability indicated there were significant physical, chemical or biological factors affecting the organisms which we were not able to measure. For example, although sediment grain size distribution is one of the most important factors controlling infaunal species distributions, almost nothing is known of the preferred or tolerated sediment grain size distributions for most infaunal species. Keeping this in mind, Tables 3-7 merely describe the distribution of the most abundant organisms collected by various methods at each beach.

Although Tables 3-7 allow general comparisons of various species from the areas sampled on each beach, a comparison which incorporates both the number of species and number of individuals in an area is of more value in examining community structure. Species diversity values and classification techniques both utilize this information.

Three species diversity values were calculated to overcome the limitations inherent in each index. We found that there was greater variability in "similar" cobble sites "within" each beach than there was between the beaches. In other words, for mixed-sediment sites, no beach had diversity values which were consistently higher or lower than other beaches, regardless of which species diversity index was calculated.

Hurlbert (1971) species-area curves use the same information that species diversity indices use, but overcome some of their limitations by reducing the actual number of organisms being compared. For example, although different numbers of amphipods were collected at each site in Figure 2, we may compare the expected number of species obtained from a sample of 32 individuals at each beach. We therefore eliminate the influence of various sample sizes on species diversity.

The species-area curves for the amphipods (Figure 2) showed considerable "within-beach" variability and indicate that no single beach had consistently higher or lower "diversity" in a random sample of 32 individuals. The faunal diversity of the fine-sand sites (Figure 3) are not significantly different from one another ($P < 0.05$) when reduced to the common sample size of 32 individuals per site. Therefore, in the most comparable and homogeneous habitats at 3 beaches, we have no evidence of the reduced species diversity which usually accompanies pollution related stress.

Classification has been used to separate polluted from non-polluted areas by many investigators (Littler and Murray, 1975; Stephenson et al., 1975; Buchanan and Lightheart, 1973). In polluted or stressed situations, the sites under stress usually cluster together due to unique faunal community. The classification of the sites by similarity coefficients (Figure 4-7) in this study further supports the conclusion that the faunal communities of the study beaches are very similar. The dendrogram resulting from the 1.0 mm samples (Figure 4) contains 3 site-groups and 4 sites with very few species (which "chain" to group 2). Group 1 represents sites with a homogeneous sand substrate, very gentle slope and the smallest median grain sizes. Group 2 represents all of the mixed-sediment sites and some sites with very sparse cobble (R25 and R29). Group 3 represents steeply sloped sites with coarse sand substrate and a low number of both species and individuals. It is interesting to note that 5 of the sites from Group 1 were compared by the Hurlbert species area curve (Figure 3) and were not significantly different from one another.

The station clusters resulting from the 6 mm screen classification (Figure 5) are very similar to the clusters for the 1.0 mm samples. Groups 1 and 2 contain nearly the same sites but group 3 has been divided in half (these sites contained few large animals). Several other sites with very few species and individuals present form meaningless groups or chain together. The results of these two classifications indicate that the cobble sites and the fine sand sites contain both large and small individuals which prefer specific habitats. Faunal communities differ much more between habitats than between beaches in this study. Within Group 2, sites R13 and R15 are very similar to each other due to the presence of large numbers of the polychaete *Lumbrineris zonata* and the close proximity of these sites to each other. There is no indication of all sites of similar habitat at only 1 beach clustering apart from similar habitats at the other beaches. Such as separation of beaches would indicate a unique fauna. The surface animal classification (Figure 6) also indicates that all of these sites have a fauna which is very similar between beaches.

When the sites are clustered by biomass (Figure 7), Groups 1 and 2 again contain the sand and mixed-sediment stations respectively, and no one beach appears different from the others within its habitat type. Group 3 consists of sites with very few species and low biomass. The species most responsible for this group of coarse-sand sites is *Clinocardium nuttallii*.

CONCLUSION

The effects of wastewater on living organisms have usually been documented as having either a growth stimulating or toxic effect. Either of these impacts could be expected to alter the intertidal faunal community if the waste concentration were great enough to affect the species present. The ac al concentration which affects the fauna is probably specific for different species and different circumstances.

When a community is severely stressed, the more sensitive species are usually eliminated and the more tolerant species increase in numbers due to the unutilized food and space which become available. We attempted to find existing community differences between beaches by several methods: species lists, relative abundances of taxa, diversity indices, species-area curves, and site-classification techniques. None of these methods indicate that the intertidal macrofaunal communities at the study beaches were under measurably different amounts of stress.

The few differences which were noted between beach epifaunal communities (e.g., surface animal abundance per areas studied on each beach) were positively correlated with differences in the suitable habitat for these organisms on each beach. The most abundant infaunal species generally occurred at all sites although 2 sites on a particular beach often had greatly different numbers of some species. Since we assume that all the sample sites within a beach are exposed to similar concentrations of effluent, we believe the differences in the abundances of the infauna within any particular beach are probably due to differences which are not related to wastewater induced stress. Whether comparing epifauna or infauna, the substrate (which generally reflects the stability and slope of an area) in the areas of comparison must be very similar in order to draw meaningful conclusions.

This study can show no measurable effects of wastewater impact on the intertidal macrofauna. However, an impact may occur which is hidden by within-beach variability or is only reflected in the more sensitive intertidal or adult organisms. While we have no direct data on larval invertebr te recruitment to the 5 beaches, the overall community similarities between the beaches probably reflects similar recruitment (there is no evidence of adult migrations into the isolated cobble areas at the 5 beaches).

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IMPACT OF SEWAGE ON BENTHIC MARINE FLORA OF THE SEATTLE AREA: PRELIMINARY RESULTS

Ronald M. Thom, John W. Armstrong, Craig P. Staude and Kenneth K. Chew
University of Washington

The condition of macro-algal communities has been used previously to both qualitatively (Dawson 1959, 1965; Widdowson 1971; Thom 1976), and quantitatively (Borowitzka 1972; Littler and Murray 1975) assess the effects of pollution on marine life. Because aquatic plants respond relatively quickly and with measurable magnitude, studies on their growth have illustrated the effects of inorganic nutrient enrichment (Widdowson 1971) and toxic inhibition (Boney 1971).

The community structure of benthic diatoms has also shown marked response to changes in water quality in fresh water situations (Patrick 1949; Hohn 1959). This work has not been extended to the marine intertidal, however.

As part of METRO's Interim Studies which were conducted primarily from June of 1974 through June of 1976, the macro- and micro-flora of 5 Seattle beaches were surveyed. The purposes of this study were to: 1) provide baseline information on the algae from the Seattle area; and 2) contrast the algal assemblages at beaches with sewage outfalls with those at a control beach. This paper is a report on results of approximately 2 years of studies and experiments on the macroalgae and diatoms at the 5 beaches.

MATERIALS AND METHODS

Macro-algae

Data on frequency and percentage cover of the epiflora and fauna was gathered quarterly for 2 years mostly from 0.25 m^2 quadrats that were permanently located at known tidal levels along transects at each beach (Thom, et al. 1976). The 5 study areas were: Richmond Beach, Carkeek Park beach, West Point beach, Alki beach, and Lincoln Park beach (Figure 1).

Algal biomass was determined by scraping all visible algae from within replicate 0.25 m^2 quadrats that were randomly placed along the transects at +0 ft., +3 ft., and +6 ft. above mean lower low water (MLLW) each season. The collected material was then identified to species, dried for 24 hours at 90° C and weighed to the nearest milligram.

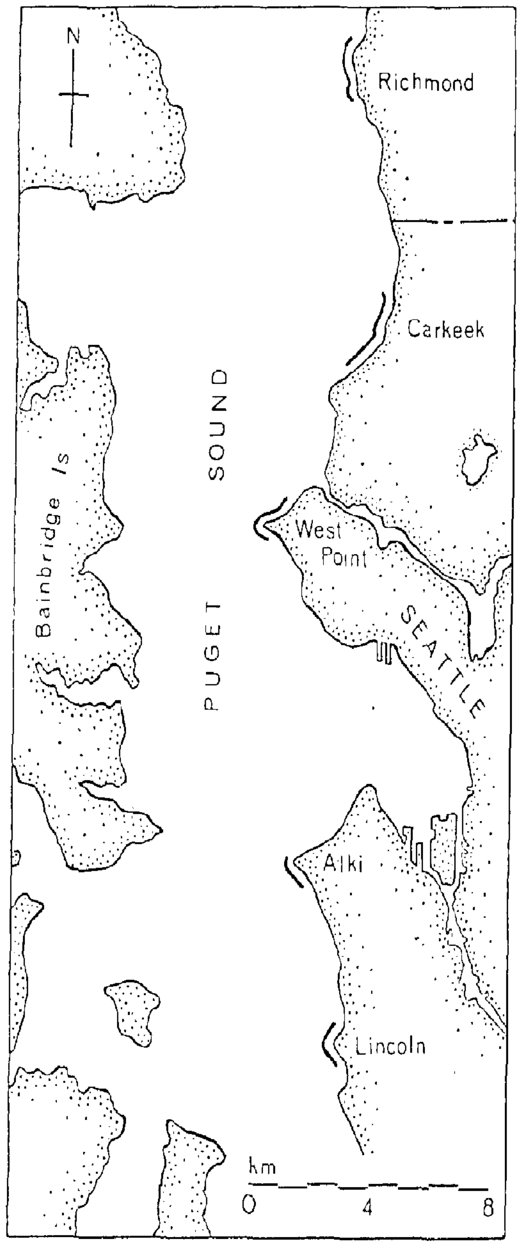

Figure 1. The beaches surveyed. The dark band indicates the portion of the beach that was sampled.

The growth rate of tagged individuals of the low intertidal brown alga *Laminaria saccharina,* was followed in the spring of 1975. A small hole was punched 10 cm above the hold fast in the blade of similarly sized plants at Lincoln Park beach (no sewage outfall) and West Point beach (largest sewage outfall). After 2 weeks, holes were punched as above, and the distance between the previous hole and the new hole was measured.

The growth and reproduction of the high intertidal brown alga *Fucus gardneri* was monitored at West Point beach, and Alki beach. Fifty randomly selected plants were collected from each study site each season during 1976. Data were taken on the length of the longest branch and the number of reproductive branches on each plant.

The density of the subtidal canopy forming brown alga *Nereocystis leutkeana* was determined by counting the number of stipes that were within 1 meter on either side of a 30 m long tape extended lengthwise through the middle of the forest. Thus, a total area of approximately 60 m^2 was sampled.

The average stipe length of the *Nereocystis* population was determined at monthly intervals from March through August of 1976. This was done by extending a tape measure from the top of the holdfast to the top of the pneumatocyst of at least 27 randomly chosen plants.

Diatoms

The assemblages of diatoms that settled on Mylar plastic plates which were attached to cement blocks anchored at the MLLW mark and exposed for 1 month were studied at West Point beach, Alki beach, and Lincoln Park beach. Random sections were cut from each plate and immersed in concentrated HNO_3 for 5 days which resulted in a sediment of cleared diatom frustules. Three permanent microscope mounts were made from each sample. One hundred cells, encountered at random on each slide, were identified to species and tallied. This resulted in a total of 300 cells per sample. If a diatom could not be assigned a specific epithet after a review of the literature, it was given a number, photographed and sketched.

Data Analysis

Intertidal 0.25 m^2 quadrat macroalgae-invertebrate data and diatom count data were analyzed using species diversity calculations and clustering. The information measure of Shannon and Weaver (1949) (H') was used to estimate species diversity at each site during each sampling period. The similarity of sites based on the frequency of macroalgal species or the relative abundances of diatom species was determined using the 'Czekanowski' coefficient of similarity (Bray and Curtis, 1957). The sites were then clustered using the group-average sorting regime' and are displayed as a dendogram.

A one-way parametric analysis of variance was used to compare percentage cover values, *Nereocystis* stipes lengths, and the measured *Fucus* parameters between beaches. The non-parametric Mann-Whitney 'U' test was used to compare the growth rates of *Laminaria* between beaches.

RESULTS

Intertidal Macro-algae

The total number of species encountered at each beach differed (Table 1). Lincoln Park had the most and Carkeek Park beach the least. Alki was second, West Point third, and Richmond Beach was fourth.

Although species diversity varied seasonally, the relative position of each study area remained fairly constant (Figure 2). Lincoln Park was always highest and West Point beach was always lowest. However, at no time did diversity measured by H' dip to a level considered low (i.e. below 1.5).

Clustering (Figure 3) of study areas based upon 0.25 m^2 communities (both epifauna and flora) revealed 3 groups. These groups, however, were not excessively dissimilar. This is probably because the most frequently found species were similar at the beaches during a season (Table 2). Samples tended to separate into an October group, a July and January group, and an April group. October samples were most dissimilar to the April samples. Additionally, Lincoln Park samples tended to be most dissimilar to West Point samples within a season.

Average percentage algal cover from the fixed quadrats between +0 ft. and +6 ft. generally peaked at the 5 beaches in July and October, and reached a low point in January (Table 3). The same trend was evident with algal biomass (Table 4). Although there were significant differences ($P < 0.05$) between values from beaches within a season, no consistent trend was noted.

The growth rate of *Laminaria saccharina* was significantly faster at West Point beach as compared to plants at Lincoln Park Beach (Table 5).

Although the mean length of *Fucus* plants at the 4 study sites during the year was essentially the same, the daily averaged growth in length during the maximum growing period was up to twice as fast at West Point (120 MGD) as compared to Carkeek Park (3 MGD) (Table 6). The percentage of branches with recepticles was also highest at the West Point sites. Areas most similar in exposure (i.e. Carkeek and West Point, north side) varied significantly ($P < 0.05$) in the percentage reproductive. Additionally, the maximum level of reproduction was reached in different months.

Subtidal Macro-algae.

Nereocystis stipes were more dense and grew significantly slower at West Point as compared to Lincoln Park (Table 7, 8). The bed at Lincoln Park, however, supported a greater biomass of this plant.

Biomass determinations indicated that brown algae dominate the understory community at Lincoln Park where as green and red algae are by far most abundant in the West Point kelp forest (Table 9).

Table 1. Number of species of macro-algae at each beach location.

	Richmond Beach	Carkeek Park	West Point	Alki	Lincoln
Green	24	27	25	28	30
Brown	12	10	19	18	17
Red	37	29	44	43	66
Total	73	66	88	89	113

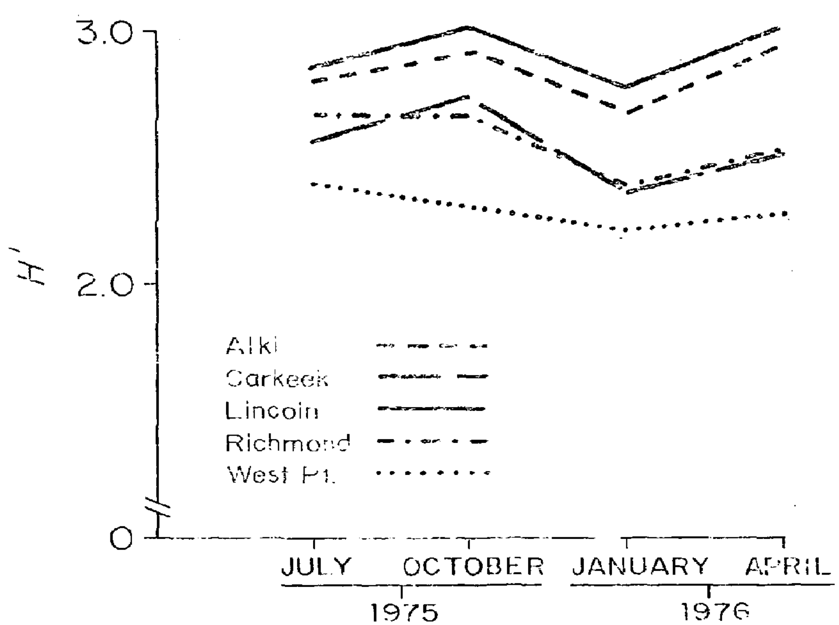

Figure 2. Species diversity of 0.25 m^2 community.

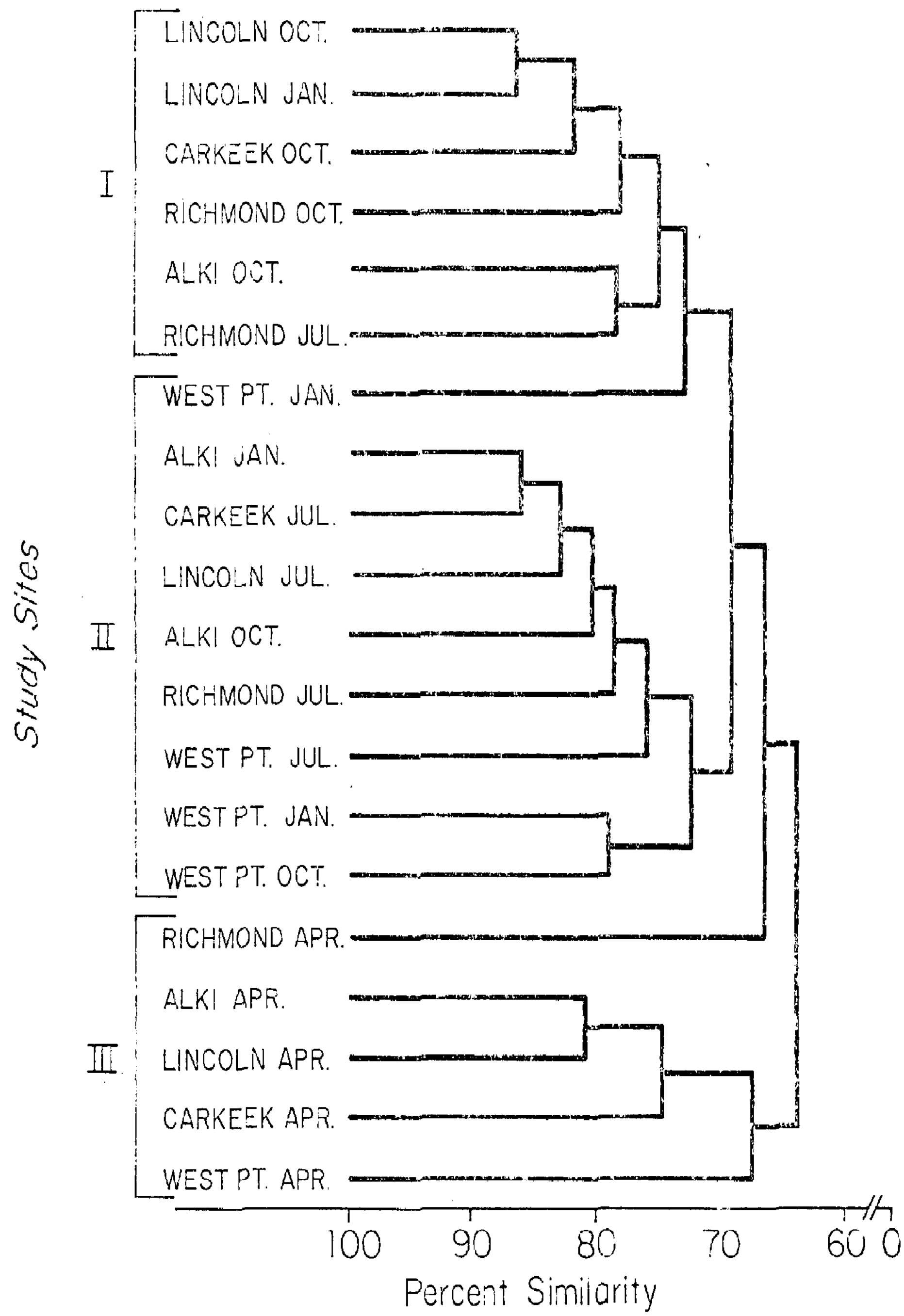

Figure 3. Cluster of study sites based on 0.25 m^2 samples.

Table 2. *Rank of top three macro-algal species at each beach each season. Tied scores were given equal ranks.*

	July					Oct					Jan					April				
	R	C	W	A	L	R	C	W	A	L	R	C	W	A	L	R	C	W	A	L
Ulva lactuca	1	1	1	1	1	1	1	1	2	1			3			2	3			
Enteromorpha intestinalis	2	2	2		2		3						3				3			
E. linza	3	3																		3
diatoms			3	3									2			1	1	2	1	1
Gigartina papillata				2				2	3	2	3	3	1		3			3		
Fucus gardneri					3					3			2							
Pterosiphonia bipinnata						2				2	3	3		1	1	3				2
Ulva expansa						3						3								
U. fenestrata						3			1			1	2	3						
Ralfsia pacifica							2			2			3		2					
Iridaea heterocarpa								3					2							
Hildenbrandia prototypus										2		3			2					3
Ulva sp.											1	2								
Polysiphonia spp.											2									
Antithamnionella glandulifera													3							
Cryptosiphonia woodii														2						
Spongomorpha spp.																2		1		
Petalonia fascia																	2		2	
Monostroma spp.																		3		
Rhodomela larix																			3	
Porphyra miniata																				2

Table 3. Percentage algal cover by season.

		1975				1976			
		JULY		OCTOBER		JANUARY		APRIL	
	N	$\bar{X}$%	S.E.	$\bar{X}$%	S.E.	$\bar{X}$%	S.E	$\bar{X}$%	S.E.
Richmond	26	20.2	6.58	30.5	8.86	0.4	0.15	16.6	7.02
Carkeek	36	49.7	7.84	28.4	8.29	4.2	2.28	18.3	5.50
West Point	28	27.8	7.48	5.7	1.46	1.1	0.81	14.6	7.36
Alki	40	40.4	8.84	34.8	7.22	6.3	2.19	25.5	6.66
Lincoln	36	27.8	8.48	11.9	2.47	3.2	0.97	21.2	5.18

Table 4. Macro-algal biomass by season (gm/.25m^2).

		1975				1976			
		JULY		OCTOBER		JANUARY		APRIL	
		$\bar{X}$	S.E.	$\bar{X}$	S.E.	$\bar{X}$	S.E.	$\bar{X}$	S.E.
Richmond	36	3.11	1.220	1.30	0.307	0.06	0.036	0.46	0.243
Carkeek	18	1.08	0.343	6.84	4.010	0.08	0.076	0.46	0.219
West Point	24	6.79	4.057	0.23	0.065	0.23	0.217	0.98	0.889
Alki	18	5.11	2.628	0.82	0.317	0.11	0.048	1.39	0.593
Lincoln	24	9.13	4.936	1.55	1.246	0.62	0.552	2.54	2.055

Table 5. The growth of <u>Laminaria</u> <u>saccharina</u> (L.) Lamouroux.

BEACH	NUMBER OF INDIVIDUALS	TOTAL GROWTH			STUDY PERIOD
		$\bar{X}$	S.D.	$\bar{X}$cm/day	
West Point	12	26.6(cm)	7.8	1.8*	May 26 to June 10
Lincoln Park	11	15.8	7.7	1.3	May 27 to June 9

* = Significant $P < 0.05$.

Table 6. Growth and reproduction of *Fucus gardneri* at Carkeek, West Point, and Alki beaches.

	N	$\overline{X}$ length over year	S.E.	$\overline{X}$ growth over max. season	max. season	$\overline{X}$ percent reproductive over yr.	S.E.	max. month	exposure rank	sewage discharge
Carkeek	200	86.7mm	3.88	0.18mm/dy	April-Aug.	17.8%	1.41	Aug.	4(low)	3 MGD
West Point North	200	87.9	3.09	0.46	Aug.-Oct.	30.5	2.35	Oct.	3	120
West Point South	200	85.5	3.81	0.25	April-Aug.	18.9	1.72	Oct.	1(high)	120
Alki	200	82.2	3.31	0.28	April-Aug.	15.1	1.37	Jan.	2	8

Table 7. *Nereocystis* stipe length, density, and standing crop. Standing crop is based upon a regression of stipe length v.s. dry weight of whole plant.

	LINCOLN					WEST POINT					
	N	$\overline{X}$ Length	S.D.	$\#/m^2$	dry wt/m^2	N	$\overline{X}$ Length	S.D.	$\#/m^2$	dry wt/m^2	t test length ($P < 0.05$)
March	30	5cm	-	-	-	30	5cm	-	-	-	
May	27	82.0	38.31	0.9	4.36	40	34.4	22.81	3.3	6.34g	6.36*
June	37	212.0	232.66	-	-	48	62.0	47.00	-	-	4.35*
August	30	353.9	172.23	1.0	948.42	30	280.0	113.25	3.8	858.58	2.38*

Significant $P < 0.05$.

Table 8. Mean rate of *Nereocystis* stipe growth (cm/day).

	March to May	May to June	June to August	Overall
Lincoln	1.7	4.2	2.0	2.4
West Point	0.6	1.0	2.8	1.8

Table 9. Top 5 * species in Nereocystis understory using biomass (1975-1976). (G = green alga, B = brown alga, R = red alga)

	Inner Bed		Mid Bed		Outer Bed	
	LINCOLN	WEST POINT	LINCOLN	WEST POINT	LINCOLN	WEST POINT
1.	Laminaria saccharina	Ulva expansa	Laminaria saccharina	Iridaea cordata	Costaria costata	Ulva expansa
2.	Ulva expansa	Ulva fenestrata	Microcladia borealis	Gigartina californica	Lamenaria saccharina	Gigartina papillata
3.	Ulvaria obscura	Iridaea cordata	Enteromorpha linza	Ulva fenestrata	Desmarestia lugulata var.firma	Iridaea cordata
4.	Ulva fenestrata	Gigartina papillata	Ulva lactuca	Laminaria saccharina	Gigartina californica	Gigartina californica
5.	Prionitis lanceolata	Ulva lactuca	Odonthalia floccusa	Ulva expansa	Ulva expansa	Antithamnionella glandulifera

OVERALL

		LINCOLN	WEST POINT
1.	(B)	Laminaria saccharia	Ulva expansa (G)
2.	(G)	Ulva expansa	Iridaea cordata (R)
3.	(B)	Costaria costata	Ulva fenestrata (G)
4.	(B)	Desmarestia liqulata	Gigartina papillata (R)
5.	(R)	Gigartina californica	Gigartina californica (R)

* In the most diverse samples, the top 5 spp. made up 91% of the biomass.

Diatoms

Diatom species diversity (Figure 4) differed both seasonally at each beach and between beaches each season. Lincoln Park samples contained the highest diversity for 4 out of the 8 samplings and never dropped below 1.84. West Point samples contained the highest diversity in 3 out of the 8 samplings with a minimum of 1.32. Alki samples were highest only once with a minimum of 1.05.

The clustering of samples revealed few easily defined groups owing to the fact that the dissimilarity between samples was generally low (Figure 5). Samples from the same beach, however, tended to group together. Group I and II (Figure 5) might loosely represent samples with characteristically solitary, closely adhering (e.g. *Cocconeis* spp) species which tended to dominate summer and winter samples (Table 10). Group III (Figure 5) dominated by April samples, would indicate samples, with an abundance of upright (e.g. *Synedra*) and tufted (e.g. *Navicula directa*) forms.

DISCUSSION

The 5 beaches that were chosen for study, with the exception of Lincoln Park, are adjacent to sewage outfalls which differ quite markedly in the volume of effluent discharged. In addition, the study areas are generally representative of the habitat types, both in proportion and composition, found in central Puget Sound. It has been documented in very localized situations elsewhere (e.g. Littler and Murray 1975; Borowitzka, 1972) that the effect of sewage effluent on intertidal communities decreases with increasing distance from the outfall. Hence, by choosing beaches with varying potential exposure to effluent, we might note this differential trend. Two problems, however, arise in the fact that by increasing the area encompassed at the study site one also introduces a large increase in variation that is difficult to reduce because the intensity of sampling of the intertidal is severely limited by the tides and weather.

A second problem arises in that the intertidal communities in our area are subjected to very dilute effluent (Bendiner, 1975). Therefore, the organisms are more apt to reflect chronic low level effects. Algae, on the other hand, are useful in this type of situation in that they are very sensitive to changes in the environment (both chemical and physical), they can be relatively easily sampled, and most species tend to be annual in appearance which renders their growth susceptible to rather short-term influences of local environmental peculiarities. Therefore, keeping in mind variability within a beach, some general conclusions can be made concerning the effects of sewage on both the macroalgae and diatom assemblages of the study sites.

There appears to be a slight reduction in number of species at West Point, Alki, Richmond, and Carkeek beaches from that found at Lincoln Park (Table 1). Although the amount of suitable (i.e. cobble or boulder) substrata might be limiting at the first 3 sites (it is well known that there is intense competition for space in the rocky intertidal, Connell, 1972), Alki has a greater proportion of rocky area available for algal attachment than does Lincoln Park, making the difference in number of species more meaningful.

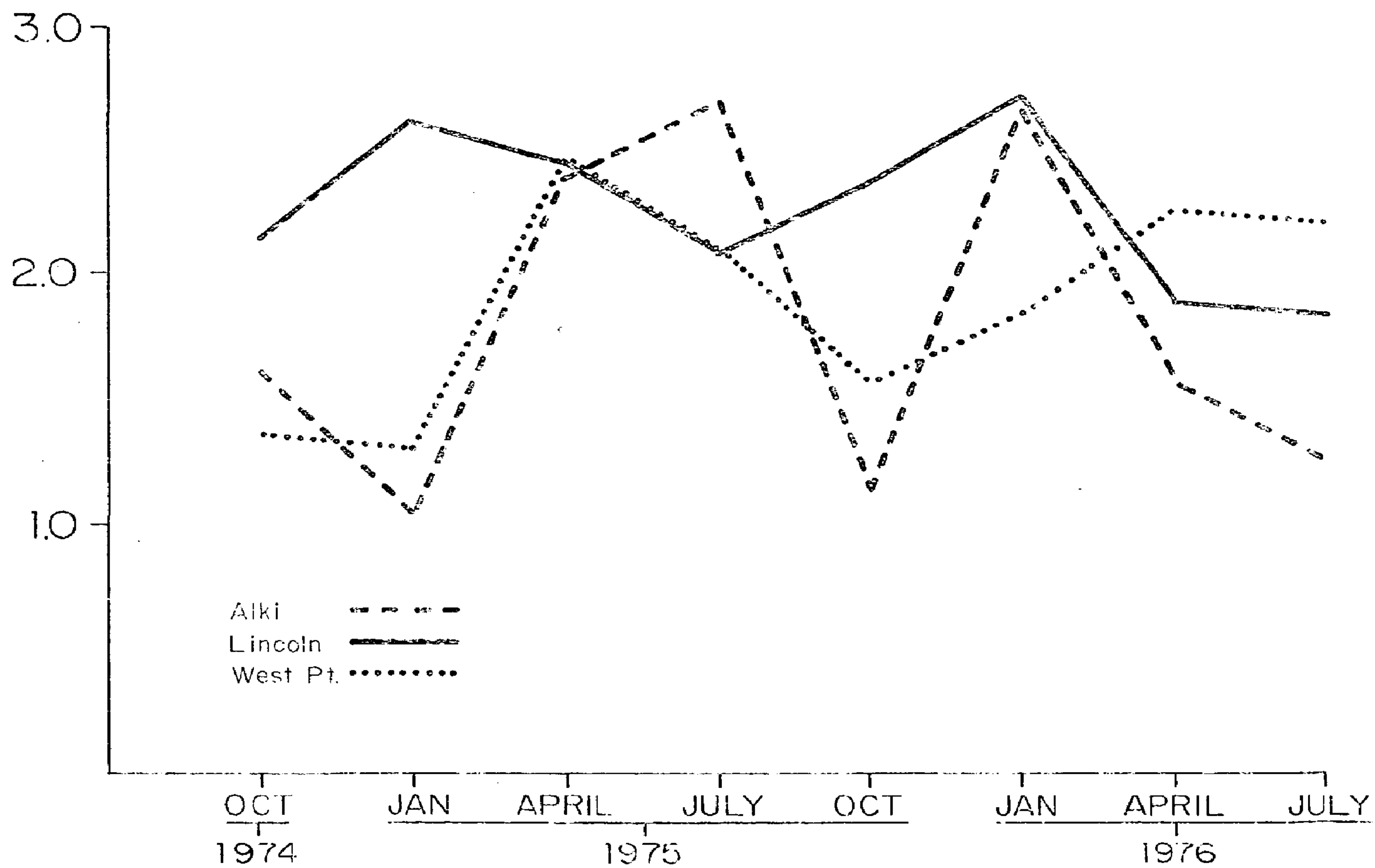

Figure 4. Diatom species diversity.

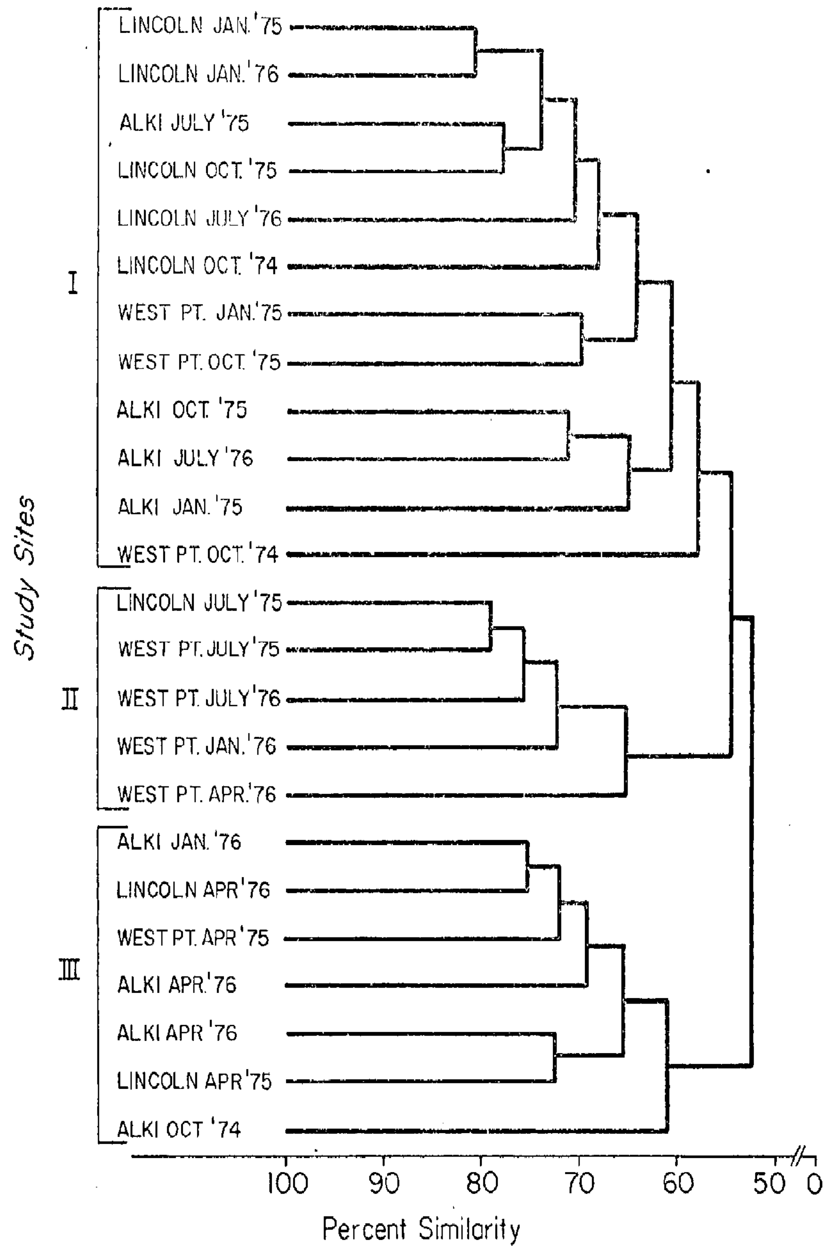

Figure 5. Cluster of study sites based on diatom flora.

Table 10. Top three species of diatoms each season.

		WEST POINT	ALKI	LINCOLN PARK
1974	October	Biddulphia aurita Cocconeis californica Rhabdonema arcuratum	Rhabdonema arcuratum Synedra tabulata Navicula directa	Synedra tabulata Cocconeis costata C. californica
1975	January	Cocconeis costata C. californica C. stauroneiformis	Coconeis californica C. costata C. stauroneiformis	C. costata C. califronica Synedra tabulata
	April	Synedra tabulata Navicula No. 50 N. directa	Navicula directa Synedra tabulata Navicula No. 10	Synedra tabulata Navicula No. 39 Cocconeis costata
	July	Cocconeis californica Achnanthes cocconeioides A. groenlandica var. phinneyi forma jaydei	Cocconeis scutellum C. californica Navicula No. 8	Syndera tabulata Navicula No. 39 Cocconeis costata
	October	Cocconeis costata C. californica C. scutellum tie C. stauroneiformis	Cocconeis scutellum C. californica C. costata	C. californica Achnanthes cocconeioides Nitzschia frustulum var. perminuta
1976	January	C. californica C. scutellum C. costata	Synedra tabulata Rhabdonema arcuratum Amphora No. 11 tie Cocconeis costata	Cocconeis costata C. californica Synedra tabulata
	April	Achnathes groenlandica var.phinneyi Navicula No. 10 tie N. No. 39	Syndrea tabulata Biddulphia aurita Cocconeis scutellum	Synedra tabulata Navicula No. 10 Cocconeis costata
	July	Cocconeis californica Achnanthes No. 4 A. No. 23	C. californica C. scutellum C. costata	C. californica C. scutellum C. stauroneiformis

Borowitzka (1972) used species diversity H') in showing the range of influence an Australian sewage outfall had on intertidal algal communities. His values were generally 1.5 or less around the outfall area. Our 0.25 m^2 diversity values, although always lowest at the beach near the outfall (which may again reflect substarta availability) and, conversely, always highest at the beach with no outfall, were never below 2.4. Thus, although species richness may be reduced at affected beaches, the community diversity remains fairly high. O'Sullivan (1971) reported that very low levels of sewage tended to raise faunal species diversity.

Clustering of stations based on the macro-epibiota has been successfully used to separate algal communities in polluted conditions from those communities considered unaffected (Littler and Murray, 1975). A similar treatment of our data (Figure 4) showed that communities were primarily affected by seasonal changes, as might be expected, and secondarily, although distinctly, spearated by differences between beaches. Lincoln Park samplings tended to be most dissimilar to West Point. Hence, the composition (i.e. actual species involved) tended to be most different between these beaches relative to the other 3 beaches.

Another factor that possibly could be affected by a pollutant is overall primary production. There were differences between beaches in average algal percentage cover and biomass (Table 2, 3), but these differences showed no consistent trends based on effluent volume.

The growth rate of the large brown kelp *Kgregaia laevigata* was significantly increased around sewage outfalls in southern California (Widdowson, 1972). At West Point, the same result was obtained with the brown seaweed *Laminaria saccharina* which may indicate that increased inorganic nutrients (especially NH_3, Collias unpublished data) in this area are significantly affecting the growth of this and, quite likely, other plants.

Several workers (e.g. Knight and Parke, 1950; Powell, 1957) have noted that increased nutrients, especially in polluted areas, affected the growth and reproduction of *Fucus*. Our studies indicate that the time and extent of formation of receptacles and the vegetative growth were positively related to the amount of sewage effluent (Table 6).

The situation was different with the subtidal kelp *Nereocystis* which grew significantly slower at West Point (Table 7, 8). This paradox is at least partly explained by the fact that : 1) The plants were three times as dense at West Point and as such were probably subjected to self-shading; and, 2) the visibility during samplings was generally less than one third that at Lincoln Park (these spot observations are supported by secchi disc readings, METRO unpublished) such that light was limiting plant growth. The ability of *Nereocystis* to grow in lower light conditions (as indicated by its exclusively subtidal habit) than other brown algal competitors might explain its ability to dominate at West Point. The shading effect of the dense canopy coupled with cloudy water are also possibly responsible for the dominance of algae adapted for low light conditions at West Point (Table 9). It remains undetermined at this time the source and nature of the material causing the cloudiness.

The diversity of diatom assemblages has been shown repeatedly to be inversely related to levels of pollution (Patrick, 1949; Hohn 1959). Diatom diversity although varying seasonally at the beaches, generally remained high at Lincoln Park while reaching low levels at Alki and West Point (Figure 6). Clustering of samples produced seasonal groups first, then a general, although not completely distinct, continuum of Lincoln Park to Alki to West Point samples within a season. Examination of the raw counts indicated that the dominant species were similar between beaches (Table 10) but the relative abundances among these species differed greatly between beaches.

CONCLUSION

Overall, there appears to be differences in the algal flora between beaches. These differences are manifested in minor modifications of community structure. Community structure is necessarily related to changes in the 'behavior' of species within each study unit. Algal species are highly, yet differentially, sensitive to environmental perturbations such as sewage pollution. Changes in such activities as growth, and the timing and success of reproduction will favor certain species in competition with other species for resources such as space and light.

Although there are minor differences between the algae at the beaches, no drastic effects, as witnessed by other workers, were noted in the studies to date. It must be said, however, that chronic effects (e.g. adaption, Stockner and Anita, 1976) are much more difficult to assess, and may, in the long run, stress the system such that large scale changes may become apparent. At this time it is impossible to estimate the amount of stress it would take to produce a large scale modification of the algal assemblage. Yet, our work indicates that the flora is being stressed to a measurable degree based on what other workers have found in more severe situations (e.g. increased algal growth rates, changes in phenology, changes in community structure). This stress by out best estimate at this time, is from sewage. We must reiterate, however, that our ability to quantify these differences was hampered by the variability inherent in most types of community analyses using conventional techniques. Further intense study is needed in what appears to be critical areas.

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SOME BIOLOGICAL, LEGAL, SOCIAL, AND ECONOMIC ASPECTS OF THE CULTURE OF THE RED ALGA *IRIDAEA CORDATA* ON NETS IN PUGET SOUND

Thomas F. Mumford, Jr.
Washington Department of Natural Resources

INTRODUCTION

In order to increase the diversity of the uses of the waters of Puget Sound, the Washington State Department of Natural Resources has undertaken a program to develop an economically feasible seaweed industry. The red alga, *Iridaea cordata* (Rhodophyta, Gigartinales) has been chosen for several reasons as an organism with which to begin. *I. cordata*, along with other members of this order, consist of up to 60% dry weight of a colloidal polysaccharide carrageenan (Waaland, 1975). Carrageenan is presently used in a variety of industrial, pharamceutical, and food processes as a thickening, gelling, and suspending agent (Marine Colloids, 1973). Related compounds from other algae, alginic acid and agar, are also widely used in similar applications. Estimated production of carrageenan in 1976 was 24,400,000 pounds with an average market price of $2.70/lb. for an estimated total market value of $65.8 million (Moss, 1977). The traditional source has been Irish moss (*Chondrus crispus*) harvested in the Canadian Maritime Provinces and the northeast United States. The source is natural beds. The sources are being fully exploited and processors have turned to other countries for additional sources. For example, large amounts of *Iridaea* are gathered by hand in Chile, dried on the beach, and shipped to the U.S. Two new culturing techniques have assured the continued supply of carrageenan-producing algae. The first is the culture of loose *Chondrus* thalli in agitated tanks or ponds. This technique has been developed by the National Research Council of Canada in conjunction with industry and is now being scaled up to full production in Nova Scotia by Marine Colloids, Inc., and Genu, Inc. (Deboer, 1977). The second technique involves the growth of *Eucheuma* spp. in the Philippines. Fragments of thalli are tied to the intertices of nets placed in shallow reef flats and harvested by hand. Marine Colloids has sponsored the research and the procedure has been very successful on a cottage industry basis (Doty, 1973; Parker, 1974). By assuring a controlled supply, the culture techniques have increased industrial demand. However, an assured domestic supply is still desired (Moss, 1977). The type of carrageenan produced by *Iridaea* is different from that from other sources and has unique properties (Waaland, 1975; McCandless, *et al.*, 1975).

Studies have been conducted on the ecology of natural populations of *Iridaea cordata* in Washington (Hruby, 1974, 1975, 1976), British Columbia (Austin and Adams, 1975), and California (Hansen and Doyle, 1976), the effects of harvesting on natural populations (Fralick, 1971; Austin and Adams, 1975), the physical parameters for optimal growth (Waaland, 1973, 1974), and the techniques for growth on artificial substrate (Waaland, 1976).

CULTURE METHODS AND RESULTS

In 1970-71, the Lummi Indian Tribal Council, in cooperation with DNR and Marine Colloids, Inc., began a harvest of natural populations of *Iridaea* in Puget Sound and the San Juan Islands. SCUBA diving apparatus and boats were obtained, divers trained and a large drier and baler set up. Because of a very poor harvest the first year, operations were suspended and later permanently discontinued. At this time, DNR under the guidance of Dave Jamison and Fred Weinmann began to experiment with growing *Iridaea* on ropes. Initial attempts were successful in getting small germlings to grow on rope, but rope outplanting was never successful. Cliff Kemp took over the program and during the summer of 1974 placed nets stretched on PVC plastic frames over a bed of *Iridaea* at San Juan Island. The set of spores on the nets was good, and on August 7, 1975, Kemp harvested an average of 4.92 ± 0.42 kg dry matter/m^2 from 4 of these nets. By October, 1975, Kemp estimated the harvested areas had regrown to the origianl density and predicted a possible yearly yield of 60-80 metic tons/hectar (6-8 kg dry matter/m^2). In September he placed 1 m^2 nets at Minnesota Reef, Barnes Island, Sinclair Island, and Sucia Island to see if the set on the nets was repeatable. Kemp left the program that fall, and I began work on February 1, 1976.

In April, 1976, the 1 m^2 nets from Barnes and Sinclair Islands were removed and taken to Minnesota Reef and San Juan Island. All these nets plus those from Minnesota Reef were cut into 0.25 m^2 pieces and restretched on PVC plastic pipe frames. These frames and nets were placed at Minnesota Reef, San Juan Island, Clam Bay near Manchester in central Puget Sound, and on Squaxin Reef, southern Puget Sound. Measurements of increase in the wet weight of *Iridaea* blade length were made on monthly or biweekly bases. Harvesting was performed on some nets in mid-June and others in mid-July, and all nets were harvested in mid-October. Harvesting was performed by cutting off the blades with sissors about 10 cm above the netting. The results here are only summarized. A more detailed account will be given in another paper (Mumford, 1977).

Of the 3 net materials tried by Kemp, white #60 cord Type 66 seine nylon twine, orange 0.25" polypropylene line, and "Vexar" plastic mesh (Dupont, Inc.), *Iridaea* set and grew well on nylon and polypropylene material but did not grow on "Vexar" mesh. The "Vexar" supported a lush growth of various kelp species (*Laminaria saccharina, Pleurophycus gardneri,* and *Alaria marginata*) by the spring of 1976.

The harvest yields from the 3" stretched mesh nylon netting was not significantly different from the 6" stretched mesh polypropylene netting. This would indicate that although the 3" mesh would give higher plant density, crowding of the plants reduced growth significantly. Experiments are now underway to determine the optimum mesh size for yield. The importance of this will also be discussed in the economics section following.

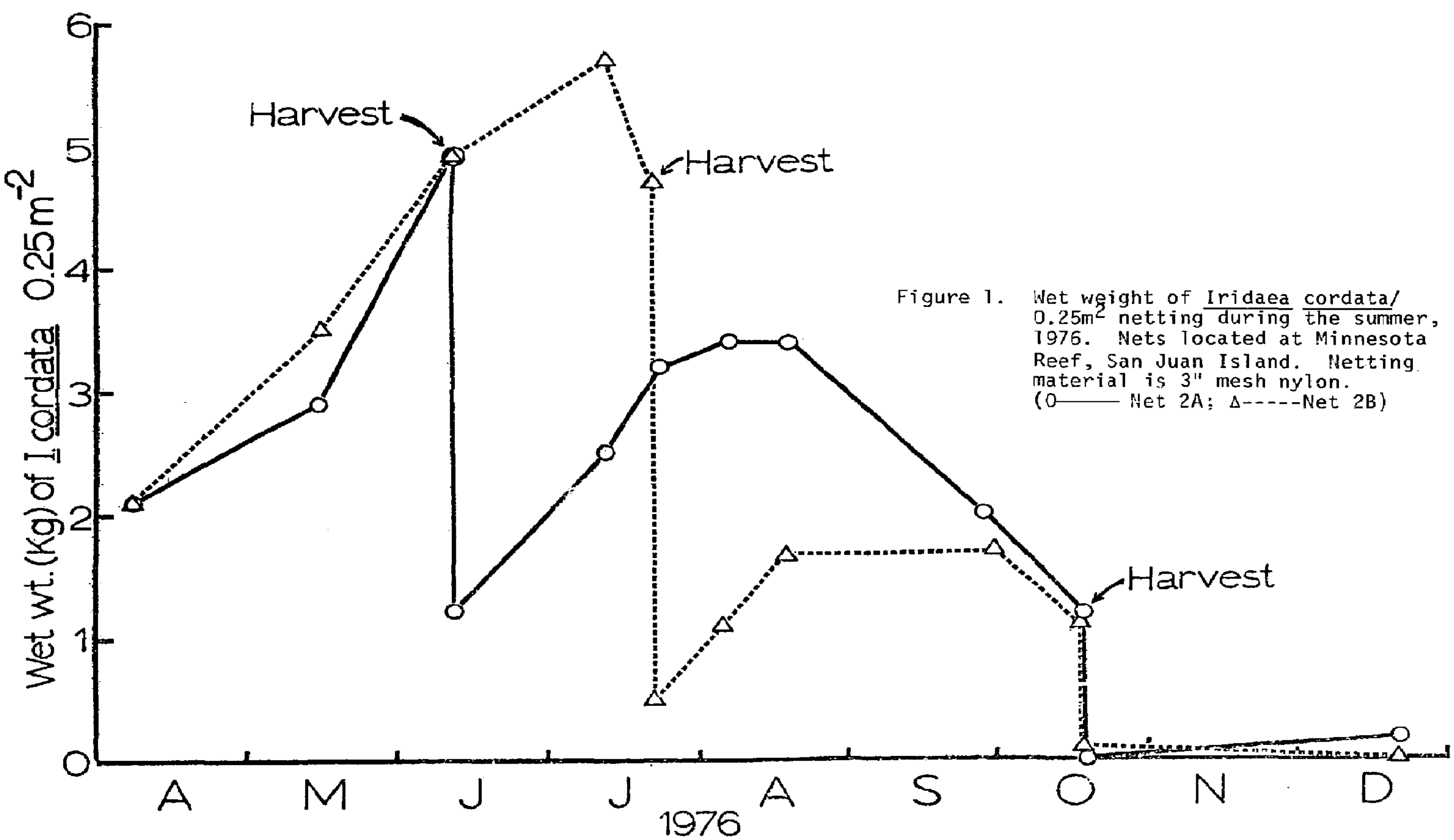

Figure 1. Wet weight of *Iridaea cordata*/ $0.25m^2$ netting during the summer, 1976. Nets located at Minnesota Reef, San Juan Island. Netting material is 3" mesh nylon. (O——— Net 2A; Δ-----Net 2B)

Harvest yields from Minnesota Reef (645.3 $\pm$ 78.8 g/0.25m^2; N=7) were not significantly different from those from Manchester (510.3 $\pm$ 77.8 g/0.25m^2; N=4). Because the percent cover on the Squaxin Reef nets was not 100%, direct comparison to the above figures is not possible, but yield was about one half of the others.

Comparison of the 1976 harvest yields from nets 2 years old (set fall, 1974; 677.2$\pm$ 76.2 g/0.25m^2; N=8) with those nets 1 year old (set fall, 1975; 44.4$\pm$ 10.4 g/0.25m^2; N=4) showed no significant difference, although the somewhat higher yields may indicate some further setting in the second year.

Yields from nets harvested on June 12 and October 18 were not significantly different from nets harvested July 18 and October 18, although by July 28 some senescence and biomass loss had occurred.

Figure 1 shows the standing crop on 2 nets made from the same net initially. Harvest was made at 2 different times. Note that neither the July 28 or October 18 harvests were at optimal times as some biomass loss had occurred in both instances.

Growth rates for all nets is shown in Figure 2. The rate is calculated by the formula:

$$R\ (\text{g salt-free dry matter day}^{-1}\ \text{m}^{-2}) = \frac{(W_2 - W_1)\ (4)(0.15)}{\Delta t}$$

Where: W_1= total wet weight of 0.25m^2 nets and frames at beginning of period

W_2= total wet weight of 0.25m^2 nets and frames at end of period

Δt= time period in days

Salt-free dry weight is 15% of wet weight (Waaland, 1975)

The peak growth occurred from mid-May to mid-August in 1976, only a 3 month period. Because of the placement of the nets in too shallow water, sunburn damage occurred during the low, daytime tides on hot sunny days in July. By mid-August, senescence had begun and blade loss was rapid. Most blades were gone by mid-October. After harvest in October, no regrowth occurred, leaving only the holdfast and bladelets to overwinter.

Harvests from all nets in 1976 gave a projected yield of 2.253 $\pm$ 0.26 g/m^2 (N=13). Nets from Minnesota Reef gave a projected yield of 3.383 $\pm$ 0.203 g/m^2 (N=4). This last figure is down drastically from the 1975 harvest of the same nets in the same location, indicating that there may be large annual variations in yield due to climatic variations.

Several observations may be made from these data. Site requirements for net placement will probably be limited only by having adequate water movement, either as a

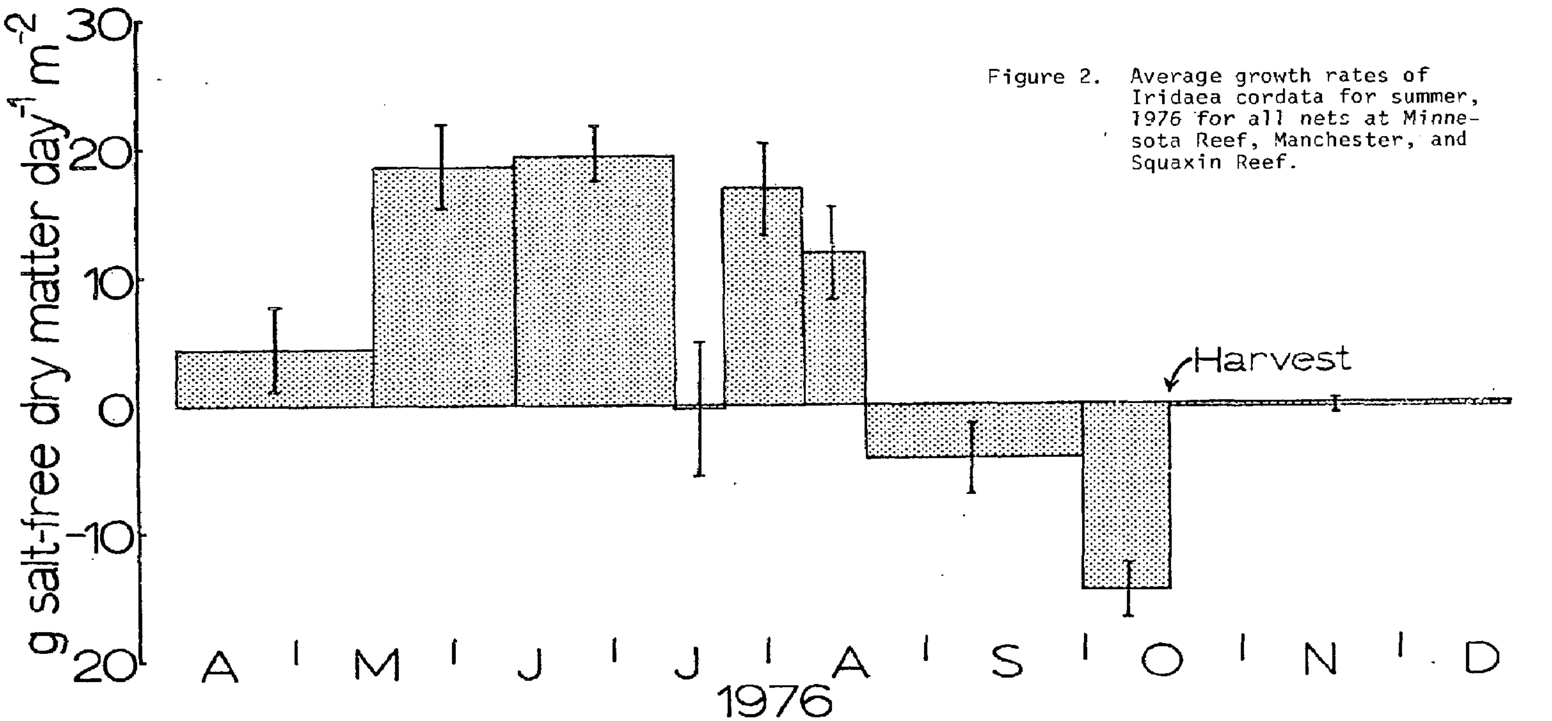

Figure 2. Average growth rates of Iridaea cordata for summer, 1976 for all nets at Minnesota Reef, Manchester, and Squaxin Reef.

result of tidal currents or wave motion. There seems to be nothing lacking in lower Puget Sound for proper growth of *Iridaea* except suitable substrate.

Those nets not completely set with *Iridaea* initially never become set at a later time on those "bare" areas. *Ulva* and *Monostroma* quickly foul these clear areas. Nets observed in March 1977 show no increase in cover of *Iridaea* over 1 year ago. On the other hand, those nets with a good, 100% cover of *Iridaea* show no loss over 1 year or have any fouling with other organisms. The perennating holdfast effectively prevents colonization by other organisms during the winter when only the holdfast and bladelets are present.

ECONOMIC CONSIDERATIONS

Only a preliminary economic analysis has been undertaken, in some instances merely outlining the system and the pieces of information needed. Costs of a research-scale operation in no way reflect what production costs may be and a cost overrun of five times what is considered the break-even point for production may be within the bounds of feasibility.

Variable production costs will include net materials, net suspension systems, seeding, maintenance and labor costs, energy for drying and baling and shipping if no local processor is available. Netting costs will be of great importance and research is underway to determine what the optimum yield: area cost ratio is. Nylon nets 2.5 years old are still in good shape with an excellent crop of *Iridaea*, so amortization of costs may be possible over at least 3 years. As netting is bought by the pound, there is great variation in area costs for different mesh size and twine diameter.

Fixed costs would include seeding facilities, harvesting machines, drying and baling apparatus, boats, trucks, docks, etc. Some salaries would also be in this category. No attempt has been made to estimate these costs and amortization schedules.

As a very rough estimate, assume a possible yield of 5 kg dried *Iridaea*/m^2 and an F.O.B. price of \$500/metric ton in Maine. This gives a gross income of \$2.50/m^2. Transportation costs are about \$120/metric ton (truck to Maine; \$0.12/kg = \$0.60/m^2) and netting costs could be as high as \$1.20/m^2 amortized for 3 years for a cost of \$0.40/m^2. This reduces income to \$1.50/m^2 from which all other costs and profits must come.

The economy of scale will have to be considered in whether this type of industrial enterprise can be undertaken with a small amount of capital and be run as a labor-intensive cottage industry, or whether it will be dominated by large corporations on a capital-intensive scheme. This, of course will be determined by economic, regulatory, and social factors that may well be quite different from what they are now, so any predictions would be mere conjecture.

The future market for carrageenan seems to be assured because of the stable supply offered by other culture systems. A yearly expansion of 10-15% is seen (Moss, 1977) with traditional markets in the food and industrial sectors. New markets may open through research aimed at developing carrageenan as an agar substitute in the medical field, and as a water-based lubricant if petroleum-based lubricants become prohibitively expensive.

LEGAL CONSIDERATIONS

All research, pilot, and industrial scale aquaculture projects must be done in accordance with the environmental and social guidelines set forth by local, state, and federal governments. Rather than deal with the actual procedure involved in getting a permit to place a structure in Puget Sound, this discussion will deal in the general considerations.

Biological research often requires great flexibility and quick action. While much planning can be done ahead of time, on-the-spot changes and plans and structures are often necessary. However, the length of time required to get a permit through the existing channels with the Corps of Engineers for the placement of every structure or modification of existing structure makes this sort of research difficult if not impossible. What is needed is a shortening or simplifying of the permit procedure or a blanket permit for a certain range of structures within a specified area for temporary research purposes. The spirit in which these safeguards of the environment were made are excellent and continue to be needed now more than ever. A project involving well-planned, permanent installations does not face quite the same difficulties as a research project. In these cases, sufficient lead time can and must be planned.

In keeping with the concept of multiple use of the water column the net structures have been designed for placement within one half meter of the bottom just below the water surface at extreme low water. No structures will be visible from the surface so boating and other surface activities will only be minimally disturbed. Possible enhancement of the fish populations around net structures is possible and may provide increased recreational use of some areas. Monitoring changes in the infauna below nets will also take place.

SUMMARY

The culture of *Itidaea* on nets still has many biological aspects that must be investigated before a large-scale commercial operation is feasible. A method for artificial seeding of nets must be perfected. This will allow even, dense sets of a particular strain or type of seaweed. Disease and herbivory will have to be studied and controlled. Growth rates under varying current and light intensities will have to be determined to allow selection of net sites. Harvesting strategies must be devised, and a harvesting machine designed and perfected. The possibility of providing seed stock for tank culture (Waaland, 1976) is under investigation, as well as increasing carrageenan content through nitrogen starvation on plants in tanks after harvesting. When the biological part of the system is better defined, then the legal, economic and social aspects will be more easily approached.

The development of techniques for the growth of *Iridaea* on nets will hopefully be transferable to other algae. Future sources of foodstuffs, agar, pharamaceuticals and large-scale biomass that can be converted to methane and other hydrocarbons may all come from seaweeds grown on artifical substrata.

The sheltered waters of Puget Sound are a unique resource and offer a site for aquaculture development unparalleled on the west coast of the U.S. Protection from storm and wave damage allows the placement of light-weight, inexpensive structures. Water quality and nutrient levels are high and tidal action assures good water movement needed for good algal growth. How aquaculture fits into the socio-economic matrix of the people of Washington will be one of the most fascinating developments in our near future.

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RISK MANAGEMENT IN PUGET SOUND

Joseph T Pizzo
Oceanographic Institute of Washington

RECOGNITION OF THE PROBLEM

The preservation of our environment has been the object of increasing concern by industry, the public, and the government. The possibility of oil and other hazardous materials spills during transport, transfer, and production operations clearly represents a potential danger to the natural resources in Puget Sound. The ecological impacts, however, represent only a part of the total impact. Although the public has become increasingly aware of ecological considerations, there is an intense interest in the positive and negative impacts to the human population and properties.

The risk of an undesirable event is continually growing, due to the increased activity to fulfill societal needs and demands. The problem is further compounded by a consideration of the socio-economic requirements, the legal implications and the political involvement of society. The potential adverse impacts on both social and natural systems and how they can be mitigated offers one of the most demanding challenges to decision makers in our industrial, scientific, and political sectors.

These potentially increasing dangers to persons, property and the environment require prompt and effective actions placing more emphasis on prevention rather than on clean-up, restoration and litigation. To justify the risk to society by pollution it is generally stated that the need for the product by society outweighs the risks involved to the population at large or to the immediate environment. It is probably assumed that there is enough resilience in the ecosystems to restabilize or refurbish any imbalances that occur. In any case, we must realize that there is a cost tradeoff that must be balanced against the benefits that society gains from the enterprise. The question to ask society is what level of risk is it willing to accept, along with its consequential results, to obtain the necessities and some amenities of daily living.

ACCEPTABLE LEVEL OF RISK

What is an acceptable level of risk? There are many agencies that are continually promoting safety programs to reduce accidents, yet people are still willing to take chances as accident statistics show (Table 1). Methodologies for computing acceptable risk levels, based on historical accident records have been developed (Ref. 1 and 2). One of the implications of these studies is that people generally will accept a level of risk for voluntary activities (skiing, flying, smoking, driving a car) which is higher, 10^{-4}, than the level of natural mortality, 10^{-6}. For involuntary activities (such as work-related risk or natural disasters), they demand a much lower level, around 10^{-7} or 10^{-8} (Figure 1). A factor not discussed, however, is the difference in involuntary nature of risk for a person who may choose to avoid living in an area which is susceptible to earthquake, floods, or hurricanes; as opposed to the person who considers himself relatively free from "involuntary risk" yet may be exposed to a massive release of hazardous material.

These studies point out that there is a greater public tolerance of minor disasters, such as automobile accidents or individual drownings, than of accidents involving the simultaneous loss of many lives, as in the TITANIC or major airline disasters. Although a risk analyst may be able to "prove" that this type of emotional reaction is not rational, the emotion-factor does exist and influences public acceptance of how regulatory agencies do their jobs. The magnitude of this factor was made readily apparent in 1969 and 1970 when the Army shipped obsolete poison gas stockpiles through cities to a disposal point. The ecological equivalent was demonstrated in the TORREY CANYON, the METULA, and possibly in the ARGO MERCHANT.

Determination of acceptable risk levels may require sampling of opinion from any public and private sectors, to obtain a consensus for development of criteria for the decision making process. Acceptable risk levels must be treated as relative values and approximations. These evaluations can give the decision maker the ability to evaluate change and provide a basis for comparison of magnitude involved. Using these approaches we may be able to establish an acceptable risk level for oil spillage and have some way of making comparisons of estimating the costs to the individual and to the community.

RISK ELEMENTS AND LOSS FACTORS

Consideration of the losses from an undesired event must include: risks to the community at large (i.e., the human population at risk, the properties at risk, the systems at risk, and the environment at risk).

Tanker Traffic and Accidents

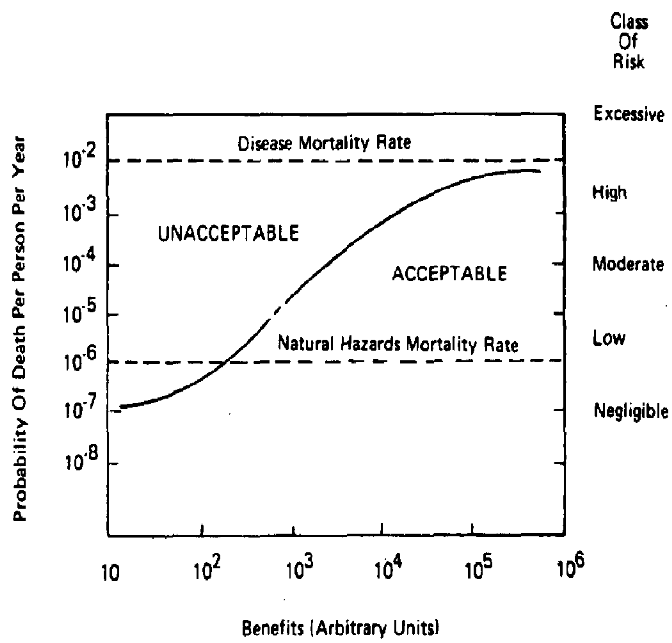
In 1974, 516 oil tankers (both crude and product) entered the Puget Sound region. Most of these went to Seattle, Anacortes, and Cherry Point-Ferndale. There were slightly more than 3,000 inbound non-self propelled oil tank vessels (barges); one-third of these went to Seattle.

On the average during 1974, about 50,000 barrels of crude and 150,000 barrels of refined products were being transferred on Puget Sound waters every day. This

Table 1 SOME U.S. ACCIDENT DEATH STATISTICS (Ref. 1) 1967, 1968

Accident	Total Deaths		Probability of Death per Person per Year	
	1967	1968	1967	1968
Motor Vehicle	53,100	55,200	2.7×10^{-4}	2.8×10^{-4}
Falls	19,800	19,900	1.0×10^{-4}	1.0×10^{-4}
Fires, burns	7,700	7,500	3.9×10^{-5}	3.8×10^{-5}
Drowning	6,800	7,400	3.4×10^{-5}	3.7×10^{-5}
Firearms	2,800	2,600	1.4×10^{-5}	1.3×10^{-5}
Poisoning	2,400	2,400	1.2×10^{-5}	1.2×10^{-5}
Cataclysm	155	129	8×10^{-7}	6×10^{-7}
Lightning	110	162	6×10^{-7}	8×10^{-7}

Figure 1 A Benefit-Risk Pattern (Ref. 1)



means that about 45 tankers, averaging from 15,000-30,000 deadweight tons (dwt), used Puget Sound ports each month. By comparision during 1976, about 213,000 barrels of crude and 174,000 barrels of refined products were being transferred on Puget Sound waters every day. The substantial increase in marine transportation of crude is due to the curtailment of Canadian crude via pipeline. This has resulted in an increase of crude tanker traffic to the refineries, which will increase even more after the Canadian supply is cut off entirely on April 1, 1977 (Ref. 3 and 4).

APPLICATION OF RISK METHODOLOGIES

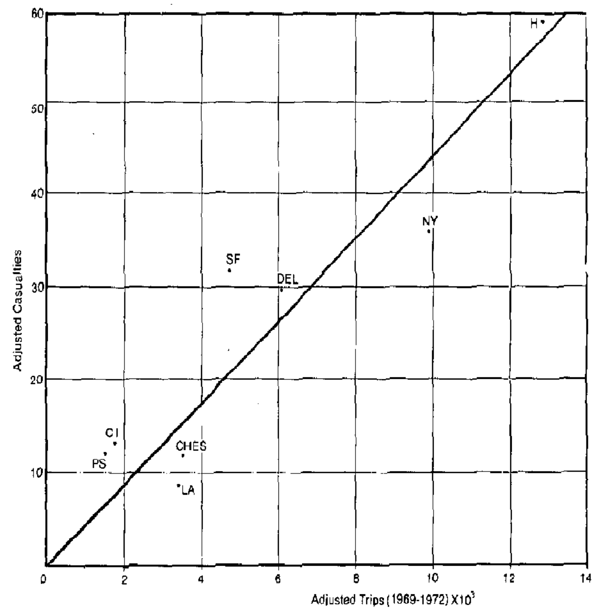
Risk methodologies have been applied successfully in the past several decades to complex systems problems in the aerospace, chemical, and nuclear industries. In the past 5 years these same methodologies have been transferred to the marine industry. OIW demonstrated this in their 1972 report Risk Analysis of the Oil Transportation System (Ref. 5). In this report a risk analysis, which is basic for the Risk Assessment Management Program (RAMP) outlined in this paper, was developed for Washington State. OIW's 1975 report Offshore Petroleum Transfer Systems for Washington State (Ref. 6) provided risk assessment forecasts of tanker casualties and spillage. A strong correlation between the number of casualties and the number of vessel trips for 7 major U.S. ports (including Puget Sound) was developed (Figure 2) and utilized in forecasting potential number of tanker accidents in Washington waters to the year 2000. A 1976 report by the Federal Energy Administration states that a similar correlation has been obtained between the number of spills and the number of tanker trips. Used properly, the results of this type of risk assessment would provide important information on potential accidents and spillage. To accomplish this decision makers need additional information on the probable impacts of such spillage, on people, property and the environment. From this data preventive actions can be taken. A total systems approach is therefore considered necessary to review adequately the hazards of navigational activities to society. The Risk Assessment Management Program is an approach to this problem.

THE RISK ASSESSMENT MANAGEMENT PROGRAM (RAMP) AN APPROACH

This paper outlines a Risk Assessment Management Program (RAMP) involving mitigating measures and control actions to reduce the risk of hazardous material pollution in Washington State. The risk methodologies are applicable to all hazardous materials. Since the current national headlines, public concern, and discussions have centered around oil pollution, we will illustrate RAMP in terms of the hazards associated with oil spills from tankers. RAMP includes interdisciplinary studies of probabilistic risk analyses, the behavior of spilled oil on water and land, resources-at-risk, socio-economic effects, and cost/benefit analyses of development options, and mitigating measures and control actions.

The objective of undertaking RAMP is to aid in the decision process by effectively reviewing the benefits of expanded petroleum activities in contrast with the costs of controlling and/or correcting hazardous operations that may have detrimental impacts on the environment. The results of this cost/benefit analysis should be meaningful to decision makers. The basic format for RAMP is outlined in Figure 3.

Figure 2



(PS = Puget Sound, Strait of Juan de Fuca, Wash. coast; CI = Cook Inlet; LA = Los Angeles, Long Beach, San Diego; CHES = Chesapeake Bay; SF = San Francisco & Bay; DEL = Delaware Bay; NY = New York, New Haven, Bridgeport, Port Jefferson; H = Gulf Coast, including Houston)

Step 1. Scenario Development

The scenarios that follow assume a level of continuity and stability.

In Washington State, the geographical focus of petroleum activities has been in Greater Puget Sound and the Strait of Juan de Fuca. (Potential activities on the outer continental shelf off the coast of Washington (Ref. 4), and those on the Columbia River and possibly British Columbia waters do add another dimension to the problem.) Limiting our projections to Greater Puget Sound and the Strait of Juan de Fuca we have the following basic scenarios:

- Traditional market only--refineries in Western Washington serve Washington, Oregon and Idaho with product.

- Transshipment to other markets--facilities in Western Washington serve additional markets beyond the traditional market area with crude and/or product.

- Independent deepwater berths--terminals at each of the refineries, independently owned and operated, handling crude and product.

- Common-use crude oil terminal--a single crude oil terminal in Washington, used by all crude oil tankers utilizing Washington waters to supply refineries, whether in or out of state.

These scenarios reflect the broad development issues now before the public. The state has struggled with these variations for many years without establishing an oil transportation policy. The situation is so fluid that the ultimate outcome is quite uncertain.

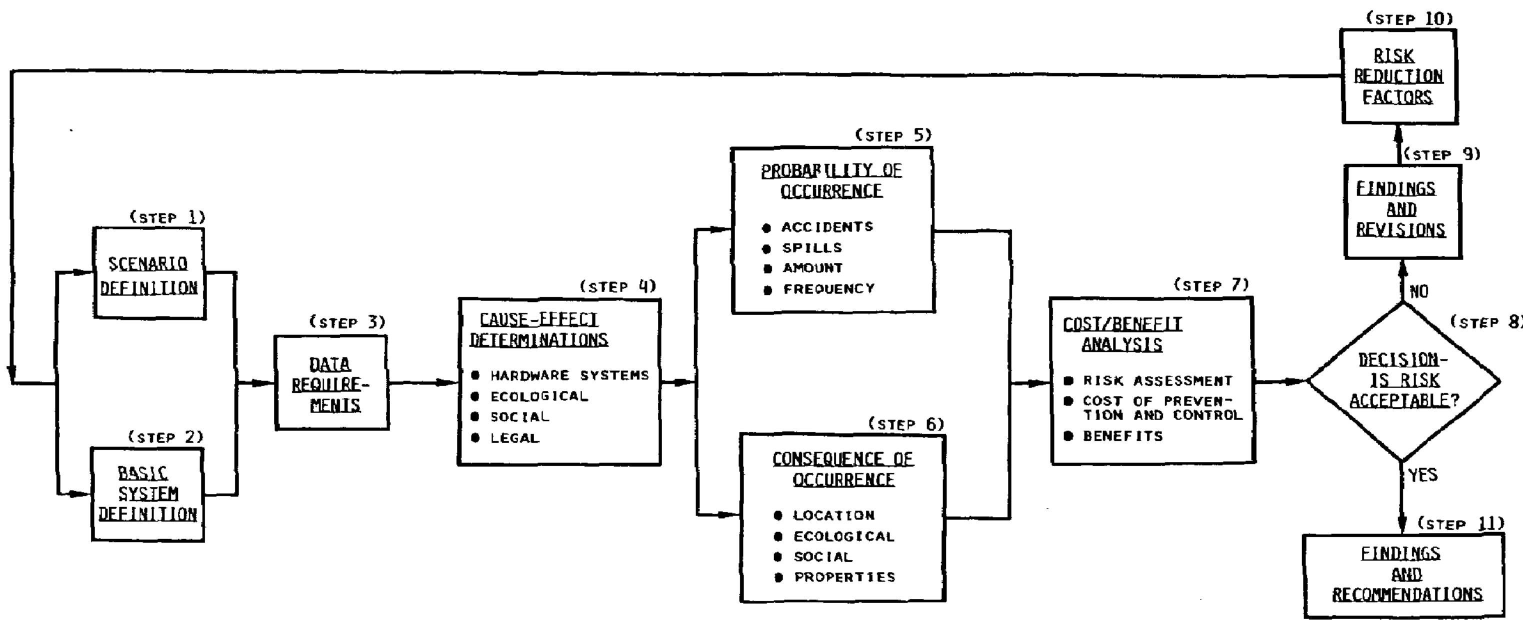
Variations of each of these basic elements as well as combinations of them are reasonable. In a dynamic, iterative program such as RAMP, other scenarios can be developed and investigated in terms of their consequential effects.

Step 2. Basic System Definitions

This step defines the system to be analyzed during transport, transfer and production phases of operations. There are numerous subsystems to be considered if the transfer and production phases are included. Restricting the system to the transport phase, however, reduces considerably the number of subsystems to be considered. Typical subsystems are:

- Tankers
- Barges
- Onshore Pipeline
- Submarine Pipelines
- Vessel Traffic System

Figure 3 - Risk Assessment Management Program (RAMP)



Step 3. Data Requirements

The logical analysis of any system requires an unbiased data base. Difficulties arise in determining the validity, the availability, and the adequacy of the data base. The data base for this program would contain:

- System elements
- Environmental Factors
- Socio-economic Factors
- Pathways and Traffic
- Safety Requirements
- Cost Factors
- Federal and State Regulations
- Historical Casualty and Pollution Incident Data
- Inherent Nature of Hazardous Material

Step 4. Cause/Effect Determination

There are several mechanisms for establishing the relationships between system elements, cause/effect relationships, environmental impacts, and preventative or corrective measures.

For example in a Gross Hazards Analysis (GHA) format, failure rates of structural elements could be considered in the context of the age of vessels, hours of operation, etc. The objective of this approach is to systematically scrutinize operations involving hazardous materials while minimizing the budgetary factors of time and cost.

The format of a Cause/Effect Step Matrix approach can be used to identify such relationships as:

- Facility Component Usage Affecting Activities--Causal Factors
- Activities--Causal Factors Affecting Potential Environmental Changes
- Potential Environmental Changes Affecting Threatened Environmental Resources
- Threatened Environmental Resources and Mitigating Measures and Cost Factors

Network construction depends on dividing the problem in relatable units, that is, causes, conditions, effects, mitigating measures and cost factors. A stepped matrix enables a continous portrayal of the use-to-cause-to-condition relationship. The linear attachment of condition to consequent condition to effect to mitigating measures to costs permits the development of a multiple response network. The framework should be an information source for a comparative evaluation of both qualitative and quantitative impacts and costs.

Other techniques that are applicable are Failure Mode and Effect Analysis and Fault Tree Analysis.

Step 5. Probability of Occurrence

The primary objective of this step is to determine the frequency and severity (potential polluting incidents. Similar analyses can be constructed for oil transfer and production operations, submarine pipelines, lightering operations shipment by tank barge, and related industrial developments such as refineries and tank farms. For purposes of illustration, casualties and spills associate(with transport operations will be considered.

Utilizing historical data on the number of casualties and the mean number of casualties per unit of exposure, the probability of the number of casualties ca be described as a negative binomial density function. This is based on the statistical theory of accidents, and assumes that the number of casualties is based on a Poisson process and that the unit of exposure is itself a random variable with a gamma distribution. This model, in the context of accident theory, is called the hypothesis of accident proneness.

It was shown in the OPTS study that the number of casualties is directly proportional to the number of vessel trips. Thus, it is possible to accurately forecast the number of casualties by considering the number of contemplated vessel trips as the exposure variable. The forecasts will vary from port to port because of variations in traffic density, port geometry, types of vessel traffic systems, environmental factors, etc.

The number of casualties leading to spills then can be calculated from historic data. Further, the percent occurrence of vessel casualties can be determined b type of casualty (collisions, groundings, rammings, and other), and by region (coastal, entrance, and harbor).

An analysis also can be made of accident reduction factors for different types vessel tracking systems. This includes preventative measures such as bridge-to bridge communications, traffic separation routes, vessel movement reporting systems, and radar.

Step 6. Consequence of Occurrence

Determining the consequential effects on the environment from a pollution incic is challenging. The variety and range of events resulting from a pollution incident present a formidable array of parameters to examine (Table 2). The majc forces that come into play are: the location of the pollution incident; the inherent nature of the hazardous substance; the quantity of material; the dynamic of the environment at the time of the incident; and the success of the clean-up effort.

The potential resources-at-risk include people, property, and the environment t may be affected. To gain a perspective of the possible consequences, Bayesian Analysis could be used to assess the relative impacts of hypothetical pollution incidents under varying environmental conditions. The Delphi Method is also a useful tool in assessing complex systems. This subjective approach relies on expert opinion and provides an experiential measure of the consequential effect on the environment.

Table 2

Parameter List

- Shoreline Characteristics
  - Type of Shore Environment
    - Rocky
    - Sandy
    - Estuary
  - Size
  - Use (Shoreline & Adjacent Waters)
    - Commercial
    - Industrial
    - Parks & Recreational
    - Residential
    - Special Areas
      - Scientific Research Areas
      - Wildlife Preserves
- Oceanography
  - Flushing Action
  - Wave Height (Hs)
  - Current Patterns
    - Tidal Cycles
    - Subsurface
  - Prevailing Winds
  - Temperature Profile
  - Salinity/Density
  - Visibility
  - Navigational Obstructions
- Terrestrial Ecology
  - Species
  - Significant Populations
  - Stability
  - Diversity
  - Food Chain
  - Endangered Species
  - Life-History
    - Habitat Requirements
    - Breeding Patterns
    - Migration Patterns
- Aquatic Ecology
  - Species
    - Mobile
    - Relatively Fixed
  - Significant Populations
    - Commercial
    - Sport
  - Stability
  - Diversity
  - Food Chain
  - Endangered Species
  - Life-History
    - Habitat Requirements
    - Breeding Patterns
    - Migration Patterns
- Material
  - Type
    - Crude (Alaskan/Middle East)
    - Product
  - Quantity (gallons)
    - <100
    - <1,000
    - <10,000
    - <100,000
    - <1,000,000
    - >1,000,000
  - Spreading Characteristics
  - Duration/Persistence
    - Evaporation
    - Weathering
  - Toxicity
- Clean-Up Efficiency
  - Oceanographic Conditions
  - Meteorological Conditions
  - Response Time
  - Recovery Ability
  - Cost/Material/Equipment Availability
- Aesthetics
  - Odor
  - Sight

An alternative method of determining ecological impacts is to construct models which can describe environmental changes. This is a very arduous developmental program involving state-of-the-art modeling and extensive baseline data collection (Figure 3).

Step 7. Cost/Benefit Analysis

To facilitate evaluation it is useful to measure the costs and benefits which would result from each decision. A methodology is necessary to estimate costs to affected industries, people and property.

The discharge of a pollutant into the environment can produce extensive economic losses to the public and associated industries. Clean-up operations divert money and manpower resources from other productive activities. Biological effects destroy valuable fish and wildlife resources. Other losses are direct physical property damage and indirect loss of the use of recreational facilities including aesthetic effects. Furthermore, possible litigation costs must be included and the original costs of installation and upkeep of the facility must be considered.

There are numerous parameters that contribute to the actual losses from a pollution incident, including such complex factors as location, weather and time of year. Some of these cost estimates are outlined in Table 3. On the other hand preventative measures as vessel design changes (double hulls), cargo size limitations, compartmentalization, additional navigational and communication equipment may introduce a prohibitive financial cost to industry outweighing the benefits. A set of general criteria that can be applied to the risk assessment process could be developed. These criteria should facilitate the grading of options, strategies, and alternatives and the determination of their viability in a regional or local context. One must be careful not to introduce biases by weighing alternatives that favor one result over another. Questions must be answered such as:

- What is the goal in mind, in terms of facility utilization in the long term and short term time span
- What is a tolerant level of pollution
- What price/task level is the local community willing to accept

The actual costs require sophisticated economic analyses and detailed modeling of the environmental effects to estimate the losses. One method of evaluating alternatives is cost-benefit analysis. The results of this analysis can be expressed as the ratio of the cost of implementing the action to the savings resulting from a particular course of action. If this information is not available, a worst-case analysis can be constructed.

Step 8. Decision for Alternative Action

At this point a decision is needed to determine if it is necessary or desirable to either improve the system or refine the analysis. If the risk assessement is unacceptable, and time and funds are still available, then the decision is obvious. If the risk assessment is acceptable, and time and funds still are available, then a decision must be made as to whether or not a more refined analysis would be

Table 3

COST ANALYSIS

Restoration Costs	Clean-Up Cost Factors	Litigation Costs	Industrial and Recreational Losses	Facility Costs
Beaches (Public and Private) Marinas Vessel(s)/ Commodity Port	• Location Distance from Shore • Oceanographic Conditions Wind/Waves/Current Time of Occurrence • Spreading/Diffusion/ Explosion/Fire Spillage/Leakage • Type of Commodity and Quantity Oil LNG Chemical Quantity Waste Water Disposal • Properties of Commodity Toxicity (Plants/Fish/ Animals/Humans Viscosity Solubility Evaporation/Weathering Explosive/Flammable Persistency Thermal Effects (Nuclear Plants) • Response Time • Available Clean Up Resources (Materials and Persons)	• Fines • Court Fees • Damage/Replacement Costs • Time Loss/Work Recreation Stoppage • Insurance	• Aquaculture • Recreation Fishing Swimming Camping Resorts • Industry Fishing Shellfish Aquaculture	• Primary Facility Materials Required Installation Costs e.g. Breakwater Operation Costs e.g. Downtime Maintenance Costs • Secondary Facilities and Operations Dredging Costs Transport Costs • Types of Facilities Storage Refinery Offshore Drilling Pipeline Pegasification Tankers Monobuoys Fixed Piers

worthwhile. If time and funds have been expended, then the analysis of the system must stop, and the findings and recommendations for further research are summarized. The decision to proceed with a follow-on program is then determined by the funding agency.

Step 9. Findings and Proposed System Revision

This step identifies the findings of a given iteration and, based on the findings, proposes revisions which should, or could, improve the system.

Step 10. Risk Reduction and Control

The Risk Reduction and Control phase constitutes the action phase of the program. During this phase, prevention and control measures are developed to achieve a satisfactory risk assessment. If necessary there will be further iterations of the program to test these alternative measures.

The degree of elimination or control of hazards results from a tradeoff between the application of improvements for removal or control of a hazard and the practicality of assuming the risk. The assumption of risk is, in most cases, a decision that must be made at the top management level, since some risks could be sufficiently large to place many parties in jeopardy. Good management projections concerning hazards and risks must be available for effective reduction of risk.

The decisions to reduce a known risk level may be implemented in many ways, including:

- Improved subsystems; equipment, testing, operations and maintenance;
- Diversion of hazardous materials to other modes or systems;
- Improved emergency response;
- Improved accident/incident and system behavior data acquisition and distribution;
- Improved systems controls, regulations and enforcement actions;
- Selection of alternative location(s) for system and operations (where possible) to minimize environmental risks;
- Reducing personnel work loads (i.e., fatigure, physical/mental strains on certain jobs)

Step 11. Findings and Recommendations

Step 11 would provide:

- An identification of the causes and effects of hazards and hazardous conditions;
- A discussion of prevention and control alternatives;

- A hazard classification to provide a qualitative measure of significance for the potential effect of each identified hazardous condition;

- A logical procedure to assess the risks involved under various conditions. The risk assessment can be made for either the present or future. This provides a formal decision-making tool which takes into account all of the important parameters in the system;

- A cost/benefit assessment comparing the effects of reducing risks with the purpose and utilization of the system.

In summary, a Risk Assessment Management Program can ideally be put into operation whenever a new technology is introduced, extended or modified. RAMP can provide decision makers with sufficient information to explore hypothetical situations, and to adequately assess cost/benefit tradeoff relationships. This information can assist in anticipating and evaluating the impacts of technological developments on all sectors of society.

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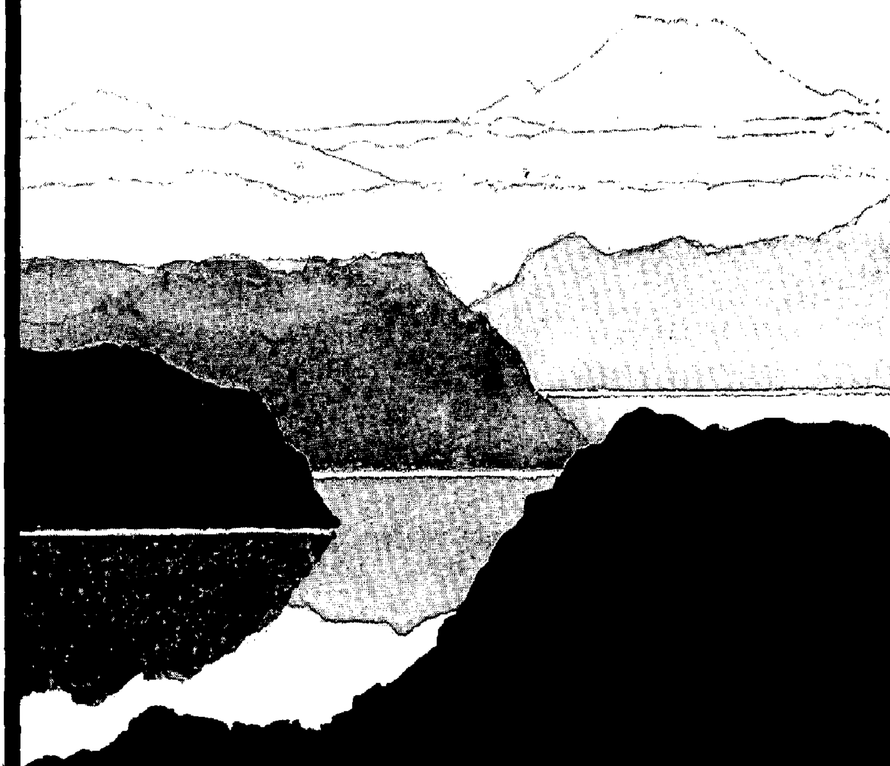
ARE RESEARCH EFFORTS ANSWERING MANAGEMENT QUESTIONS?



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PUGET SOUND RESEARCH-- MAKING RESULTS AVAILABLE

Howard S. Harris
National Oceanic and Atmospheric Administration

The session this morning will address two topics:

1. Are present research efforts redundant?

2. Is research really supplying the answers to management questions?

I will restrict my introductory remarks to the second topic, for several reasons. I have the feeling that current research is not redundant and, for that matter, some redundancy is not necessarily bad. Some aspects of Puget Sound have been studied for many years but emphasis has changed as new problems are identified: we are now looking at the effects of synthetic organics, for example, a relatively new topic.

Finally, while we may have only scratched the surface in some topical areas, a long period of research may be required to produce usable results in new areas. Meanwhile, decisions are being made about the uses of the Sound. While recognizing the need for additional research, I see an equal need to make our present knowledge available as a basis for more informed management decisions. I see the need for making our present research results more readily available.

Let's look at the question "Is research really supplying the answers to management questions?" This supposes that the questions facing managers and planners are, in fact, being translated into the kinds of questions typically posed in a research project. I suspect the true situation is somewhat different. Questions are not being posed to the scientists by the managers. Rather the scientists are defining research as they see the need and proceeding on the assumption that the results will be applicable to the management of the Sound. This may or may not be a good assumption.

At this point I must distinguish between various "managers." I am using the word to mean those whose actions may affect several of the multiple uses of the Sound, those that operate in a multidisciplinary or multi-resource context. They may be at the state or federal level but equally likely at the county or local level of government. Those concerned with Shorelines Management or Coastal Zone Management are an example. I am not talking about managers of specific resources, such as the fishery. Managers of specific resources are usually quite aware of research in their area and the implications for their particular resource. Frequently they have access to a scientific or technical staff, a luxury not always available at the local level.

In addressing myself to the informational needs of managers, I am not overlooking the needs of others that participate in the management of public resources--the public, individually and collectively, commercial interests, special interest groups, elected officials.

Let's suppose that a question or a decision arises from the proposed siting of a facility near the shoreline. How are we as researchers making available information on the marine aspects of the Sound in such a way as to improve the collective judgment on the siting of the facility? A decision will be reached using the information at hand. But time may be short, the implications for the resources of the Sound obscure, and no expert readily available. It is not surprising that shoreside considerations appear to dominate the decision process--political, economic, social considerations--for each has its advocates and the consequences of the decision are considered. How can equal weight be given to marine considerations?

This problem has bothered our staff from the inception of the MESA Project. About a year ago we discussed the problem with the Oceanographic Institute of Washington. They undertook an investigation which led to a report to us entitled "Oil in Washington: Applicability of Models to Marine Environmental Management Questions and Ecological Impacts." One part of this work is of interest here, the part that identified questions facing managers and planners in state and local government. The Oceanographic Institute used 3 sources of information: Literature Review, the results of past and current work of the Institute, and, most important here, personal interviews with 23 state and local government officals.

Their report contains a list of 480 management questions, less than 40% of which can be categorized as environmental, and not all of those were marine environmental.

It is apparent that the marine environmental management questions were not perceived by these government officials as being the most critical ones raised by the oil transportation issue. The main concerns of the majority were socioeconomic in nature, centering around land use and the economic dependence or independence of their jurisdiction or activities on oil activities. "Quality of Life" appeared to top the list.

The principal marine questions either concerned the impacts of spillage on resources which have commercial and recreational use and importance or revolve around the central issue of acceptability of risk of damage from such spillage. However, the questions were expressed in layman's language rather than that of the scientist, expressed as the synthesis of a large body of knowledge rather at the level of detail addressed by most research.

While the OIW study addressed the specific issue of oil and Puget Sound, I expect that the results would not have been greatly different for many other issues--wastewater disposal, for example.

What can be done, beyond recognizing the problem? I start with the assumption that a great deal is known about the Sound--not all to be sure--but enough to provide some basis for rational management decisions. If this is true, then we must make a greater effort to place this information in the hands of those concerned with the management of the Sound.

I'd like to describe one contribution that the MESA Project intends to make. As many of you know, the Project is supporting additional research in certain areas where information is needed and is presently inadequate. But during the course of this research, we are mounting an effort to synthesize and disseminate presently available information.

We have approached the University of Washington Sea Grant Program for assistance in formulating a strategy. We posed 3 questions.

1. Is there a need for a publication or series of publications that relate the state of knowledge about the Puget Sound environment?

2. If such a need exists, what information should be included and how should the information be presented?

3. What kind of effort would be required to produce the publication or series of publications?

To address these questions, Sea Grant reviewed a similar project resulting in a series of monographs on the New York Bight, surveyed potential users around the Sound, and, with the help of an 18-member advisory board, developed a plan for a Puget Sound publication series.

The report from Sea Grant concludes that there is a need for a series of publications, consisting largely of descriptive writing but including some maps and illustrations, written at a level about equivalent to "Scientific American." A total of 14 volumes or topics was suggested, topics such as water properties, circulation, geology, shoreline processes, plankton, intertidal biota, fish, bordering estuaries and marshlands, mammals and waterfowl, recreation, commercial fishing, demographic patterns, and institutional considerations. Each volume might run from 30 to 50 pages.

We are now working out the final details of the publication series and it is likely that it will be underway in a few months. Two to 3 years will be required to complete publication of the series.

In conclusion, our project is making an effort to bridge the gap between the researchers and the managers. Others here are also concerned with this problem. Collectively we may approach a solution.

I would like to suggest the following philosophy regarding research on the Sound. I suggest that research is not completed until results are available in a format useful to managers and planners, elected officials and the public. In some circles, this is called technology transfer.

There must be a continuing dialog between researchers and managers to develop a definition of what research is needed, how the results of that research will be worked up, and on what schedule.

We cannot consider our research completed until the results have been made readily available.

MANAGEMENT CONCERNS IN PUGET SOUND RESEARCH

William A. Johnson
Washington Department of Natural Resources

This is a rare opportunity to express our views on the use of Puget Sound. I hope we make the most of it. Bert L. Cole gave the keynote address on Wednesday. He identified some of the Department of Natural Resources responsibilities but to reiterate, the Department is the proprietor of most lands owned by the state of Washington, comprising a total of 5 million acres. One million acres is agricultural land, 2 million acres are forest land and 2 million acres are aquatic lands.

DEPARTMENT OF NATURAL RESOURCES PROPRIETOR OF THE LAND

The agriculture and forest lands are managed to maximize the economic return, or the most dollars to the trusts, such as common schools, university and State Forest Board lands, etc. The aquatic lands which include the bed of all navigable waters, tide lands, shore lands and the state harbor areas, are managed to maximize the greatest long-term public benefit. This basic difference in purpose of economic return on trust land and public benefit on aquatic land is required by the legislature, and as you can imagine provides management an entirely different array of objectives to choose from in adopting land use allocations and programs.

Organization Scope

One additional difference is that Department of Natural Resources serves a proprietary function and is not regulatory. As the proprietor the Department manages 1,300 miles of tidelands, 6,700 acres of constitutionally established harbor areas and 2,000,000 acres of beds of navigable waters. To produce the most benefit from these marine lands it is necessary to manage for a multitude of purposes. Multiple purpose is a management concept that recognizes the primary use but also provides for compatible secondary uses to maximize the benefit of present and future generations.

Goals

These concepts of management must be in harmony with the best interests of the public. We look upon this as a public trust which must:

1. Provide more opportunities for public use of public land

2. Provide greater return of food for cultivating and harvesting the sea

3. Enhance the state's position as a shipping center

4. Protect biological productivity and natural systems of near-shore environment

5. Compensate the Public for the withdrawal of lands by private activities which reduce options available to the public.

Objectives

Public trust concepts are further broken down into operating programs. The Department management programs can be broken down into these categories.

1. *Public use*, in which we have programs in oyster spat collection, beach marking for boaters, beach walking, beach combing and general enjoyment, deepwater habitat improvement, shellfish improvement.

2. *Aquaculture*, the culture of marine organisms in semi-protected waters of Puget Sound, Willapa Bay and Grays Harbor. Most common activity is in clams, oysters, seaweed and salmon. Over 5 million pounds of geoducks were harvested in 1976 on state land.

3. *Commercial use.* Approximately 110,000 acres of state owned tideland and beds of navigable waters are leased. Commercial leases are in harbor areas for piers, wharves and aides to navigation, water dependent industry, shellfish removal, booming and rafting and mineral removal.

4. *Environmental, educational and scientific reserves*. Aquatic land reserves have been set aside for areas of identified ecological, educational and scientific importance. Other areas have been identified and set aside as unique marine areas.

5. *Limited use*. Certain state owned tidelands are for one of several reasons, unsuited for public use beach development and the interests of the abutting upland residents are recognized with regard to their utilizing state owned tidelands for private enjoyment--such as shellfish growing, residential dock or swim floats.

6. *Anchorage area.* As manager of bedlands of Puget Sound, the Department of Natural Resources must allocate aquatic areas to meet demands for moorage. Small boat harbors will require space along the shores to meet the boater

demands. These facilities must be properly located so as not to eliminate our remaining natural beaches, yet be provided in an area that can withstand new traffic and use patterns.

Role of Proprietor

The mechanism by which the Department exerts its control of land use is the lease, use easement, permits and deeds. The Department's management plan and the use agreements regulate land use activities over time and space as well as provide an income return to the public, plus other benefits such as good environment in which to live. Each lease request must be carefully evaluated for proper siting and water dependency requirements. For example, commercial use requirements should, for the most part, be concentrated in areas of first class tide lands and harbor areas.

With this identification of the role that the Department of Natural Resources plays in the total management of Puget Sound, I have focused on involvement that we play. It is the involvement of the proprietor of the land. The uses that Puget Sound is subjected to are the immediate concern of the land owner. The effect that the users have on the water and on the land determines the benefits that the people of this state receive from their land. It is the avowed management objective of the legislature of this state plus the Board of Natural Resources, that we maximize these public benefits.

There are many demands placed on Puget Sound; there are demands made on the same area, resulting in conflicts. It is these conflicts that require and demand that the proprietor has good basic information, whether in the way of a management plan, inventory, or cause and effect information regarding uses so that the manager can correctly assess and then harmonize these uses. The day when an individual can block off or set aside a segment of the Sound for personal consumption, whether to preserve his view or because some adverse impact may occur and based on personal concerns, object to all other users, is past. We simply must get all the benefits out of this natural resource that we can, while minimizing the adverse effects on the environment. We need good data so the manager knows what will be the resultant action when the decision is to proceed.

Somehow we must all address outselves to the true multiple use concept. This is like having our cake and eating it too. We must proceed carefully so as to maintain credibility with all benefactors but our objective must be to accommodate the multitude of demands for public use, aquaculture, commerce, etc., to maximize the public benefit for all the people while minimizing the adverse impact on our environment. And certainly a part of the answer is effective research and responsive management.

RESEARCH CONSIDERATIONS

Let us now look at the scientist researcher and his relationship with management. A frequently heard question voiced by natural resource management these days is "Do our research efforts really answer the questions asked?" In other words, dollar for dollar, are we, or is the taxpayer, getting what we are paying for? In order to answer this question as adequately as we possibly can, we must take into account some of the following research considerations.

Is Research Relevant

Are the questions asked by management relevant to the current problems facing them? It is possible that both management, and the researcher as well, have failed to do their homework,in other words, obtaining background information to determine the needs for improved management techniques--for example, literature reviews, field surveys, and the like. These preliminary efforts, as previously mentioned, would indicate whether a particular question has or has not been addressed in the past. In addition, if the questions regarding potential research are not relevant, there is the lack of challenge and/or incentive to the researcher that must also be considered. As a result, there could be the possiblility of minimal effort developing and a high turnover rate of qualified personnel to carry on the work.

Looking at it another way, shouldn't the researcher remain ahead of present day problems and needs; at least a portion of his work load should be devoted to this area, to provide incentive. Does management always know exactly what the problems are or will be?

Priorities

Priority establishment, pertaining to research needs, may also be lacking. Here management personnel may not be emphasizing or communicating to the researcher or research unit the most important goals and/or objectives it wishes to carry out. This would be necessary from a scientist's point of view, in order to prepare adequate experimental designs and work plans, to implement the research effort.

Procedures

The researchers handling of the following situation may also be a determining factor in providing the necessary answers to management inquiries. The responsible scientist must assure management that:

1. A good preliminary background study has been made
2. Correct experimental designs have been developed, given that management has defined problem and to what accuracy the answers must be known
3. Adequate work plans have been drawn up
4. Approved and/or accepted methods are being implemented
5. Follow-up procedures have been provided for and carried out.

The researcher is also responsible for the collection of sound, adequate data. If this is not the case, then an ever-widening credibility gap will be the inevitable result with questions remaining unanswered and money wasted.

Completion Data and Distribution

Lack of a pre-determined completion date for any research project may also be a factor in not providing needed answers to questions instigated by management. Again, if a designated date of completion has never been set, incentive and challenge for the scientist may be lacking. Realistic determination of completion date is critical and project leadership is essential. Closely aligned with setting a project completion date is the availability of an effective mechanism to distribute and communicate the results of research, accomplished to the parties concerned. Without a workable mechanism (or system)--such as publishing or reporting procedures--investment in research is, and always will be, too expensive.

Management Responsibilities in Research

Of increasing concern is whether management is aware of its responsibilities and willingness to provide the much needed leadership and guidance to channel effective two-way communication. The following are just a few thoughts to consider pertaining to this area:

1. Do management and research facility efforts reflect adherence to sound management and scientific principles? If so, are the short-and long-term environmental considerations for the welfare of natural resources well understood by both parties?

2. The possibility exists that management does not always provide enough detail as to their objectives, therefore research will not be complete--in other words, approximations are the result--again, complete answers may not be possible.

3. Of great importance is need for increased awareness by management that the questions asked should not reflect the needs of management only . . .the needs of field personnel must also be considered, otherwise the input may be in such a form as to be useless to those who will ultimately use the results of research--the field personnel!

4. Many scientific questions are also very complicated in nature and require the coordinated effort of several individuals to share the total responsibility for completed research. If handled properly, the probability of the questions being adequately answered are increased.

5. Responsive, considered feedback from management is essential in building confidence. Good dialogue is a must.

When studying natural biology there may not be real answers to some of the questions asked by management; best estimates, or approximations, may have to suffice.

APPLIED RESEARCH PHILOSOPHY

We need to turn to a basic philosophy that will result in the greatest return on the applied research dollar.

Continuous

To begin with, the system should be modeled--a systems approach. This will require the close cooperation of an inter-disciplinary team and a leader who is familiar with the concept. Then the parameter can be clearly delimited, and the sensitive interrelationships determined. This will enable priority decisions to be more easily made.

A steady, ongoing program, in the long run will produce more information at a reduced cost. A uniform, interdisciplinary team approach, organized for the long haul has the greatest productivity in not only specific information but fall-out types of information commonly result and come as a bonus. This is difficult to accomplish, however, and individual egos may need to be suppressed. All benefits resulting from planning and management go to the program having continuity.

Continuous Support

Whereas any program having longevity or continuity obviously must have continuous support, my point here is a level, uniform rate of support, not an up and down, hot and cold program, but one funded fairly uniformly so a uniform level of activity can be established and basic information secured. An example is the Department of Fisheries in studying razor clams and because their program was an ongoing one, they found razor clams do not move as they had thought, but remained in the same general area.

Crash Programs

Crash programs do not recognize all of the problems and oftentimes result in a clear definition of the problem rather than the solution. An adequate program does need proper funding--uniformity again. Crash programs result in short-term goals, short-term personnel and generally poor quality and resource information.

Fundamental

You are all aware that generally the primary barrier to a research project is the dollar cost and the time required to conduct research. Research projects are generally associated with a particular site, which is undesirable because study must be repeated again and again answering the same questions repeatedly. Research must be conducted on fundamental subjects that can be extrapolated into broad areas of similar nature. Dredge spoil disposal studies for example, can be extrapolated to other proposed sites instead of making complete study on each new site. This consumes the time and money resources available as mentioned above. Any reluctance to accept information from previous studies must be countered by the scientific community. The scientific community and management must foster and support fundamental research attitudes. Local government decision makers must be convinced that previously attained information adequately answers local concerns.

The present regulatory system favors the process of individual project research. Local government, in attempting to be responsive to concerned citizens, encourages specific project research that may have limited real value, and due to costs and time, discourage proponents by eroding away their resources. The learning institutions and regulatory agencies often do not discourage this. We must all work together in this effort to responsibly answer questions raised by concerned citizens. Our natural tendency is to appear responsible and proceed with a new study which we already can predict the results, to quiet the opposition. Ongoing projects must be reviewed for cause and effect to check earlier predictions, and records must be kept for future reference. Research must be by class of activity rather than specific projects, and we must develop a concept of indicators so we can be predictive rather than reactive. This may be hard to sell.

APPLIED RESEARCH NEEDS

Let us review some needs that we have in aquaculture.

Continue and extend basic aquaculture research. Additional forms of aquaculture such as oyster farming have been conducted for many years and the techniques of culture have been quite well perfected for each area where culture has been traditionally carried on. However, there are many possible improvements which are needed to improve the economics or achieve maximum survival and quality of product. These might include increasing survival of oyster seed after planting by fifty percent or more, controlling or eradicating oyster drills. Obtaining a domestic supply of oyster seed which would provide for present and all future needs of the industry. Some of these answers have to be aquired by intensive research while others might better be accomplished by demonstration activities. Clams and mussels in the Pacific Northwest have really not, up to this point, been cultured in the true sense of the word except by one operator on Whidbey Island. On most existing clam farms harvest is predominately of a natural crop with the farmer expending most of his effort to prevent losses from natural causes and develop rotational harvesting schemes. Some farmers are perfecting techniques for clam bed habitat improvement; however, a great deal of work would be necessary to establish a reliable source of high quality clam seed for both industry and private beach owners. Considerable evaluation is also desirable to determine those techniques of habitat improvement that would achieve the greatest enhancement for the most economical cost. Mussel culture, for practical purposes, must be developed from the beginning, but can utilize techniques perfected in Europe as well as results of small scale research currently being carried out in this part of the country. Culture of crustaceans such as crabs, crawfish and Puget Sound shrimp appear to be technically feasible but so far have not reached the stage where economic feasibility can even be evaluated. Their cycle requiring 3 to 4 years before maturity is reached, makes cultural activities somewhat unfeasible at the present time. However, as world demand increases for quality sea food products, culture of one or more of these species may be expected to become technically and economically feasible. The basic research at the present time on the topics mentioned above should be continuous, on a study, rather than a crash basis, so that as the time for full-fledged cultural development comes near, enough basic work has been completed so that a pilot-scale commercial activity can be initiated with confidence.

Resource Inventory

The nature of shellfish resources, both intertidally and subtidally, is fairly well known. However, there is need for a great deal more inventory work on the intertidal publically owned tidal lands for those species currently having or anticipated to have high demand. There has been inventory work on the subtidal populations of clams and geoducks during the past 6 years but while these inventories have fairly well been located the principal beds, there is much work needed to quantitatively measure the abundance of the most valuable species in the area from low tide to 60 feet. Inventorying should be prioritized by blocks appropriately situated as to geographic location and depth. In other words at this time a much more comprehensive quantitative survey of geoduck populations in and addition to existing leased areas would be valuable while an inventory of geoduck stocks lying between 60 and 150 feet should be deferred until just before we can anticipate the need to initate harvest on these deep water stocks. Inventorying does not mean the covering of every foot of ground subtidally, but to establish and consistently sample grid patterns that allow reasonable accurate estimations of abundance and for those species which burrow into the ground, samples to include size and age and subsurface substrate conditions. Survey reports should also include other significant features such as weather and tidal currents as measures of availability or harvesting feasibility. Stock assessment is essential for long-term project success as well as safeguarding the even flow of the resource to industry and the consumer public.

There is a need to establish a data bank that would incorporate an electronic data processing system that would record significant information as mentioned earlier and which could be retrieved when needed. Much information has been gathered over the past 6 to 10 years for specific purposes. What is needed is a uniform system to first gather information comprehensively and then place the data in a computer system to be retrieved again when needed, thereby extending the usefulness of information gathered. A classic example that we have today is with horse clams. You know it wasn't long ago that they were a resource to toss aside so the valuable clams could be picked. Not so today. Conditions have changed and if we had the ability, based on past survey data, to retrieve information such as locations, water depth, water conditions, etc., our position would certainly be more advantageous.

Protection of Shellfish Environment

Successful maintenance of viable shellfish populations is highly dependent upon suitable water quality. The most sensitive phase of life of any of the shellfish species tends to be during the time of egg fertilization and larval development. Optimum reseeding requires highly favorable conditions. Marginal reseeding can frequently take place when conditions are within the tolerance range but not ideal. However, when excessive industrial pollution or when the presence of excessive amounts of nutrient material occurs, the water may become toxic. There is a direct result or a secondary result due to plankton blooms. In these instances, reproduction may very well be affected. And if chronic, it could result in serious degradation of formerly healthy beds.

Another significant problem is where the habitat itself is totally eliminated such as the unmitigated destruction of a particular habitat by, for example the building of a marina. Mitigative procedures, such as building a new clam bed in another area, cannot be expected to completely replace the loss, but could at least serve to reduce its impact.

There are still instances where the habitat of the shellfish population is not seriously affected but the presence of sewage pollution will preclude the utilization or marketing of the stocks of shellfish which are filter feeders unless corrective measures can be taken. The productivity of a particular area may have to be written off for many years until cleanup of the sewage problems allows marketing of the species again.

In addition we have allocated areas to shellfish production that are currently not cultivated and these areas must be protected from degradation through sewage and industrial outfalls. The Aquatic Land Manager must be very sensitive to development on the upland or shore lands that will affect these future aquacultural areas.

Population Dynamics

Population dynamics is the scientific study of fertilization, reproduction, growth and maturity to learn enough of population to predict a harvest pattern. Best example of this is our geoduck resource where it has been determined reasonably well what kind of a standing crop there is. We have determined some of the requirements under which spawning and larval development take place but we have not been able to accurately determine the rate of natural reseeding and although we are gathering knowledge, we are still somewhat uncertain as to the actual age of maturity of full grown adult animals. Said another way, we are still uncertain of the age at which growth rate slows down and the effect of population density on mean annual growth. However, even knowing that we do not have all the information we still believe it is logical and we are obligated to attempt to develop harvest management plans for a sustained yield harvest. Therefore, certain conservative assumptions have to be made on rates of reseeding and growth to harvestable size. Experience will demonstrate how valid these assumptions are; therefore, the management plan that we establish at this time will be modified in 3 to 5 to 8 years depending on the measurement and actual evaluation of results. One must bear in mind the possibility that in certain areas significant reproduction may not occur more than once in 20 years.

Management Plans

The ingredients were mentioned before under population dynamics. The only remaining concept that needs to be stressed is that a manager cannot wait until all the information is available before some steps are taken to develop or implement a management plan or for that matter, a limited entry system. Considerable judgement has to enter into the decision and then enough follow-up work done so that the adequacy of the plan can be assessed, and where inaccuracies are demonstrated, adjustments must be made to take this into account.

Critical Research Needed

One of the very important areas is for additional research to be done so that there can be a reasonably accurate assessment of the conditions leading to or the actual occurrence of time and intensity of spawning and subsequent settlement of the larvae. It may actually be that the development of a prediction system such as has been done with Pacific oysters will enable aquaculturists to take timely and appropriate steps to maximum utilzation of the seed stock.

Another area has to do with the assessment of the habitat and if, for example, it is found that a pest or predator is causing significant damage to the animals, corrective steps should be taken either if economically feasible of if the condition is so serious that corrective steps must be taken regardless of cost.

What I am saying is that the use of Puget Sound will increase, no doubt about that. There will definitely be impacts from these uses. Our goal in management will be to structure this use to minimize negative impacts. The uses must be conditional to provide for as many activities as possible. We can manage to maximize public benefit thru multiple use. The simple way out is to manage for a single use, which surely would not tax our capabilities. The real test is to squeeze in more activities. Multiple use--recognizing a primary use while conditioning secondary uses--will result in getting more out of this land. The ultimate alternatives would be to restrict all uses or to have no regulation. Society must be in between these two extreme alternatives. We face some hard decisions and a tremendous selling job but we simply must find a way within the regulatory system within which we must operate, to satisfy concerned citizens, minimize negative environmental impacts while increasing the uses of Puget Sound.

Accepted applied research is the answer.

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INFORMATIONAL REQUIREMENTS OF THE WASHINGTON COASTAL ZONE MANAGEMENT PROGRAM

D. Rodney Mack
Washington Department of Ecology

In preparing a shoreline or coastal zone management program, traditional planning dogma would have one go through a process of the formulation of goals/objectives, inventory, analysis and plan development and implementation. While there are several variations of this basic process, invariably there is provision for early and extensive data gathering and analysis, upon which information the planning program is subsequently based. By and large, the Washington program abbreviated this process and proceeded directly into the planning and management phase with an admittedly cursory data base.

The reasons for this are several: local governments were faced with unrealistically short deadlines for developing their programs; local expertise in data gathering and analysis, other than land use data, was largely non-existent; technical expertise from state and federal agencies and the academic community to assist local government was generally lacking; and the immediate implementation of the regulatory aspect of the program (i.e., the substantial development permit process) caused workload problems that distracted from the less urgent data gathering efforts.

Local shoreline programs and the information upon which they are based have, without exception, emphasized the land side of the land/water interface. The reasons are fairly apparent: (1) that's where the action is in terms of development proposals and day-to-day decision making; (2) the technical aspects of the programs were invariably developed by local planning departments having expertise in land use planning; and (3) in this state, with the exception of work done by the State Department of Natural Resources, very little has been done in developing and implementing planning and management concepts for areas lying seaward of the ordinary high water mark. In the overall scheme of things, however, I feel that the circumvention of an extensive information gathering phase at the beginning of the program has not hurt the program and has probably in fact been beneficial.

I say this after reflecting upon our experience to date and in observing the parallel efforts taking place in other coastal states as they develop their respective coastal zone management programs. Too often, I think, the implementation of management programs is unduly delayed and a certain impetus is lost when the predominate focus is on developing an increasingly comprehensive and sophisticated information base. Too often, the implementation of the controversial regulatory aspect of a management program is continually deferred until "more and better data are available," a process we all know can be endless.

I think that in this state we were fortunate, and the authors of the Shoreline Management Act demonstrated great insight, in that the shoreline permit system was made effective on the date the Act became effective. It recognized in the Act that decisions on proposed developments had to be made in the face of less than perfect information, although it was also recognized that the quality of decisions would improve as local programs progressed through inventories and regulation promulgation toward completion and adoption. To a great extent, therefore, the final local master programs address those issues and contain criterion in response to real projects that were reviewed and the real decisions that were required during program preparation.

In contrast, I fear that many coastal states, particularly those not having the clear broad mandate of our Shoreline Act, will encounter substantial difficulties in moving from a planning and information phase to an implementory/regulatory phase.

As indicated previously, the data collection phase of local shoreline master programs tended to be, in most jurisdictions, less than optimal. By law, local government was charged with conducting a comprehensive shoreline inventory to include but not be limited to ". . . the general ownership patterns of the lands located therein in terms of public and private ownership, a survey of the general natural characteristics thereof, present uses conducted therein and initial projected uses thereof." With the acknowledged deficiencies in the area of "survey of the general natural characteristics," the Department has directed significant time and monies through the coastal zone management program to improve that aspect of the information base.

That effort, and other related data activities such as our Baseline Program, will be focussed in our forthcoming Coastal Zone Atlas. The Atlas project has grown out of an increasingly emphatic demand from planners and decision makers at all levels of governments and developers in the private sector for a uniform, accurate and sufficiently detailed data base upon which to make decisions and initiate activities. The Atlas, being designed and prepared by Drs. John Sherman and Carl Youngmann in the Department of Geography, University of Washington, will ultimately include data previously collected but never presented in a mapped format, as well as data now being collected which has never been available previously. The two most significant aspects of the Atlas, however, are that it will emphasize information that has been subjected to some degree of interpretation (as opposed to single geographically distributed data) and that it will present that information at a map scale sufficiently large (1:24,000) to allow site analysis. The first of these warrants some elaboration.

The critical test of all information proposed to be included in the Atlas is its utility in management. For that reason, the Atlas will not contain information typically found in similar atlases, such as for example the spatial distribution of various fish and shellfish. That information, while of general interest to the layman and the practitioner, does not furnish any particular guidance in answering questions about specific proposals. What is needed in management is the additional step of professional analysis and judgement of that simple distribution of data to point out critical areas and a sense of priority or significance of that species in that area.

We have specified that the Atlas is to be a multi-color, printed product, since that format is generally felt to be the most comprehensible format available for both professional and lay persons. We have also attempted to expand the potential utility of the Atlas information (and the ability to update that information) by the use of an intermediate digitizing process. With the data thus stored, it will be possible to display, correlate and analyze various combinations of data (in a McHargian fashion) and assign various subjectively--determined/weights to the data to achieve development suitability maps.

One of the major pieces of information to be included in the Atlas is what we term an inventory of coastal drift sectors. We define a drift sector as a segment of beach or shoreline within which uninterrupted sediment drift or transport takes place and which contains within its boundaries all sources of that sediment, both erosional and depositional. The significance of the data, from a management standpoint, is the ability to identify critical areas which either contribute to the sediment flow or are otherwise subject to accretion or erosion. This will allow the encouragement of development in areas which will cause minimal disruption of the natural coastal dynamics system.

A second major study, being conducted by the State Department of Natural Resources, is a survey of coastal slope stability. Such information has obvious implications in guiding development away from the most hazardous areas and in providing information for taking corrective engineering actions in stabilizing sites for development. The Department of Natural Resources is also expanding and expediting their mapping of basic geological information.

The Washington Department of Game is under contract with the Department of Ecology to inventory and describe the upland and intertidal habitats in the coastal zone. Habitat types are classified by soil type, slope, land use, and animals which inhabit each habitat. The information, when completed, will help significantly to fill the void mentioned previously related to the natural characteristic aspect of the local shoreline inventories.

A study of major significance is being conducted for the Department by Mathematical Sciences Northwest which will describe and map critical areas in Washington's marine waters. The nature of the study is illustrative of the basic Atlas philosophy to present information which has been subjected to analysis and judgement. The critical area study will define and map specific populations which, because of unique oceanographic conditions, provide the major sources of recruitment for adjacent populations. The second criteria for definition of critical areas are breeding, nesting, feeding and resting areas, as well as nursery areas.

In addition to these Atlas projects, we have retained the firm of Corff and Shapiro to develop guidelines for the management of those areas lying seaward of the intertidal area. The study will include an extensive legal analysis of various legislation pertaining to the marine area as well as an identification of the various authorities and responsibilities of the federal, state, and local levels of government. The balance of the study will be devoted to identifying and analyzing potential uses that may occur in the marine water area, by habitat, and intial work will be done in recommending guidelines and performance standards which would apply to those potential uses. Ultimately, it would be desirable that the information derived from this and subsequent studies would be used to enhance local shoreline master programs and would form a consistent body of policy which state and federal agencies might utilize in analyzing proposals in the marine water area.

In summary, more and better information will not, per se, lead to better decision making in our coastal zone. Decisions have been and will continue to be made on the basis of political tradeoffs, on the basis of past precedents and in favor of the individual rather than the resource. In addition to data quality and quantity, we need to acknowledge that decision makers rarely have the capability of using basic data in their deliberations and we therefore need to direct increasing emphasis on presenting information to the decision maker in a more immediately usable format.

SYMPOSIUM PARTICIPANTS

PROCEEDINGS
March 23–25, 1977
A Washington Sea Grant Publication
University of Washington • Seattle

Merle Adlum
P.O. Box 1209
Seattle, WA 98111

Rick Albright
Washington Dept. of Game
509 Fairview N.
Seattle, WA 98109

John W. Armstrong
College of Fisheries
University of Washington WH-10
Seattle, WA 98195

Steven H. Aubert
METRO
410 W. Harrison
Seattle, WA 98104

Grant Bailey
URS Company
4th & Vine Bldg.
Seattle, WA 98121

Clifford A. Barnes
Dept. of Oceanography
University of Washington WB-10
Seattle, WA 98195

Brian Bebee
METRO
410 W. Harrison
Seattle, WA 98101

William Bendiner
Applied Physics Lab
University of Washington HN-10
Seattle, WA 98195

R. Bergstrom
Rebco Marine
1660 Harbor S.W.
Seattle, WA 98116

William B. Beyers
Department of Geography
University of Washington DP-10
Seattle, WA 98195

Steve Bingham
Brown & Caldwell
600 First
Seattle, WA 98104

Lawrence E. Birke
Northwest Pulp & Paper Assn.
555 116th N.E.
Bellevue, WA 98104

Lewis J. Bledsoe
NORFISH Center for Quan. Science
3737 15th N.E. #204 HR-20
Seattle, WA 98105

Paul R. Bonin
Pacific Science Center
200 2nd N.
Seattle, WA 98109

Ralph S. Boomer
U.S. Fish & Wildlife
2625 Parkmont Pl.
Bldg. B3
Olympia, WA 98502

Mark Boule
Corff & Shapiro
812 Smith Tower
Seattle, WA 98104

David C. Brubaker
University of Washington IES
19925 130th N.E.
Woodinville, WA 98072

William A. Bush
Wash. State Parks & Recreation Comm.
P.O. Box 1128
Olympia, WA 98504

Jeffery R. Cadell
353 N.W. 88th
Seattle, WA 98177

Kenneth K. Chew
College of Fisheries
University of Washington WH-10
Seattle, WA 98195

Karen Clark
METRO
600 First
Seattle, WA 98104

Bert L. Cole
Public Lands Bldg.
Olympia, WA 98504

Eugene E. Collias
Department of Oceanography
University of Washington WB-10
Seattle, WA 98195

Janet Condon
METRO
410 W. Harrison
Seattle, WA 98119

Richard Conway
Business Administration
University of Washington DS-10
Seattle, WA 98195

Michael A. Craig
Crowley Environmental Services
2763 13th S.W.
Seattle, WA 98126

Joseph M. Cummins
EPA - Region X
Box 283
Manchester, WA 98353

Ray Dalseg
METRO
600 First
Seattle, WA 98104

Eric Davidson
Thurston Regional Planning Council
Courthouse Annex
Olympia, WA 98501

H. Tom Davis
Montgomery Engineers
1301 Vista
Boise, ID 83705

William A. Dawson
Wash. Wildlife Study Council
2029 E. Miller
Seattle, WA 98112

Dennis Derickson
Snohomish County Planning Dept.
Court House
Everett, WA. 98201

Chris Dlugokenski
U.S. Fish & Wildlife Service
2625 Parkmont Bldg. A
Olympia, WA 98502

Ralph Domenowske
METRO
600 First
Seatte, WA 98104

Andrew L, Driscoll
N.W. Environmental Consultants
219 Madison S.
Bainbridge Island, WA 98110

Donald Dubois
Environmental Protection Agency
1200 6th
Seattle, WA 98101

Richard D. Duncan
Commercial Oyster Hatchery
7736 Yeomalt Pl. N.E.
Bainbridge Island, WA 98110

Alyn C. Duxbury
Dept. of Oceanography & Div. of Marine Res.
University of Washington WB-10
Seattle, WA 98195

Claire Dyckman
Huxley College
Unesco Env'l Transactions Project
603 38th
Seattle, WA 98122

P.T. Dyer
Institute for Environmental Studies
University of Washington FM-12
Seattle, WA 98125

Curtis C. Ebbesmeyer
Evans-Hamilton Inc.
6306 21st N.E.
Seattle, WA 98115

Griffith Evans USN(Ret.)
4005 S.W. Massachusetts
Seattle, WA 98144

Glen Farris
METRO
410 W. Harrison
Seattle, WA 98119

Richard S. Fleming
Institute for Environmental Studies
University of Washington FM-12
Seattle, WA 98195

Richard H. Fleming
Dept. of Oceanography
University of Washington WB-10
Seattle, WA 98195

Rella E. Foley
METRO
17805 210 N.E.
Woodinville, WA 98072

Michael B. Fraser
MRM - OSU
645 S.E. Viewmont
Corvallis, OR 97330

Bruce Frost
Dept. of Oceanography
University of Washington WB-10
Seattle, WA 98195

Luci1le Fuller
Institute of Governmental Res.
University of Washington JM-10
Seattle, WA 98195

Rich Fullner
U.S. Army Corps of Engineers
P.O. Box C-3755 Seattle Dist.
Seattle, WA 98124

Robert H. Gedney
7540 N.E. Hidden Cove Rd.
Bainbridge, Island, WA 98110

William B. Gillespie
King Co. Public Works
Rm. 976 King Co. Adm. Bldg.
Seattle, WA 98104

Charles L. Gott
SEA USE Program
1101 Seattle Tower
Seattle, WA 98101

Liz Greenhagen
P.O. Box 1089
Ocean Shores, WA 98569

Dan Haggerty
City of Seattle
806 Municipal Bldg.
Seattle, WA 98104

Cherie Harnden
Summit School
10944 23rd N.E.
Seattle, WA 98125

Howard Harris
MESA Puget Sound Project
7600 Sand Pt. Way N.E.
Seattle, WA 98115

Gary Harshman
Oceanographic Institute of Wash.
312 First N.
Seattle, WA 98109

William L. Haushild
U.S. Geological Survey
1 Washington Plaza
Tacoma, WA 98402

Jon Helseth
Evans-Hamilton Inc.
6306 21st N.E.
Seattle, WA 98115

Douglas A. Hilderbrand
METRO
600 First
Seattle, WA 98104

K. Holm
METRO
600 First
Seattle, WA 98104

Cynthia Jaeger
METRO
410 W. Harrison
Seattle, WA 98119

Lt. David C. Jarrett
NOAA Corps
1801 Fairview E.
Seattle, WA 98102

Robert Jeffrey
Skagit Wildlife Lab.
Dept. of Game
1100 E. College Way
Mt. Vernon, WA 98273

Thomas L. Johnson
Oceanographic Inst. of Washington
312 First N.
Seattle, WA 98109

William A. Johnson
Div. of Marine Land Management
Dept. of Natural Resources
Olympia, WA 98504

Bill Karp
College of Fisheries
University of Washington WH-10
Seattle, WA 98195

Gerry W. Kelly
Weyerhaeuser
5401 W. Mercer Way
Mercer Island, WA 98040

Gary L. Kline
U.S. Fish & Wildlife Service
2625 Parkmount Lane Bldg. B-3
Olympia, WA 98502

Ronald Kopenski
MESA Puget Sound Project
NOAA
3711 15th N.E.
Seattle, WA 98105

Gary Kucinski
Port of Tacoma
P.O. Box 1837
Tacoma, WA 98401

L. Kulzer
METRO
600 First
Seattle, WA 98104

Hap Leon
Pacific Rim Planners Inc.
5606 14th N.W.
Seattle, WA 98107

Patricia Levison
Summit School
3818 Linden N.
Seattle, WA 98103

Bill Liechty
Water Supply & Waste Section
DSHS MS 4-1
Olympia, WA 98504

John H. Lincoln
Dept. of Oceanography
University of Washington WB-10
Seattle, WA 98195

Edward R. Long
MESA Puget Sound Project
NOAA
3711 15th N.E.
Seattle, WA 98105

Maureen Loomis
856 S. Central #9
Kent, WA 98031

Phillip Loomis
856 S. Central #9
Kent, WA 98031

Ed Lukjanowicz
NAVFAC
Bldg. 5B 2nd Floor
Seattle, WA 98115

P.S. Machno
METRO
600 First
Seattle, WA 98104

Rodney Mack
Washington Dept. of Ecology
Olympia, WA 98504

Doug Magoon
Div. of Marine Land Mgmt.
Dept. of Natural Resources
Olympia, WA 98504

Brian W. Mar
University of Washington FX-10
Seattle, WA 98195

Ann Martin
Dept. of Comm. Dev.
306 Cherry
Seattle, WA 98104

R.D. Martin
Urban Planning
University of Washington JO-40
Seattle, WA 98195

Steve Martin
U.S. Army Corps of Engineers
P.O. Box C-3755
Seattle, WA 98124

Robert Matsuda
METRO
410 W. Harrison
Seattle, WA 98119

Terry McCann
City of Tacoma Planning Dept.
Rm. 335 County-City Bldg.
Tacoma. WA 98402

John C. McConnell
Washington Dept. of Ecology
4350 150th N.E.
Redmond, WA 98052

Richard F. McGinnis
Dept. of Biology
Pacific Lutheran University
Tacoma, WA 98447

Cam McIntosh
Oceanographic Inst. of Washington
312 First N.
Seattle, WA 98109

Mariam L. Meacham
Jefferson Co. Shoreline Comm.
P.O. Box 92
Hadlock, WA 98339

Katie Mills
City of Tacoma Planning Dept.
Rm. 335 County-City Bldg.
Tacoma, WA 98402

Gary R. Minton
URS Company
4th & Vine Bldg.
Seattle, WA 98121

Robert J. Morrice
METRO
410 W. Harrison
Seattle, WA 98119

Jim Mullan
U.S. Fish & Wildlife Service
2625 Parkmont Bldg. A
Olympia, WA 98502

Thomas F. Mumford, Jr.
Dept. of Natural Resources
Olympia, WA 98504

Lawrence C. Murdock
Oceanographic Inst. of Washington
312 First N.
Seattle, WA 98109

Stanley R. Murphy
Division of Marine Resources
University of Washington HG-30
Seattle, WA 98195

Ahmad Nevissi
Fisheries Center
University of Washington WH-10
Seattle, WA 98195

Annette Olson
Bureau of Outdoor Recreation
Rm. 990 Federal Bldg.
Seattle, WA 98174

John Osborn
EPA
1200 Sixth
Seattle, WA 98101

Carol Ovens
Division of Marine Resources
University of Washington HG-30
Seattle, WA 98195

Richard Page
METRO
600 First
Seattle, WA 98104

Spyros Pavlou
Dept. of Oceanography
University of Washington WB-10
Seattle, WA 98195

Larry L. Peterson
METRO
600 First
Seattle, WA 98104

Joseph T. Pizzo
Oceanographic Inst. of Washington
312 First N.
Seattle, WA 98109

Robert Rath
Oceanographic Inst. of Washington
312 First N.
Seattle, WA 98109

Raymond Reilly
MESA Puget Sound Project
NOAA
3711 15th N.E.
Seattle, WA 98105

Jeff Rice
URS Company
4th & Vine Bldg.
Seattle, WA 98121

T.G. Rice
METRO
13555 Roosevelt Way N.
Seattle, WA 98133

Katie Robertson
856 S. Central #9
Kent, WA 98031

Admiral James S. Russell
7734 Walnut S.W.
Tacoma, WA 98498

Florence Sands
Pacific Science Center
200 2nd N.
Seattle, WA 98109

Stanley S. Saxton
METRO
600 First
Seattle, WA 98104

William R. Schell
College of Fisheries
University of Washington WH-10
Seattle, WA 98195

Saskia Schott
Inst. for Marine Studies
University of Washington HA-35
Seattle, WA 98195

Jack Serwold
Shoreline Community College
16101 Greenwood
Seattle, WA 98133

Betsy Shedd
Summit School
202 13th E.
Seattle, WA 98112

David H. Shinn
City of Seattle
310 Arctic Bldg.
Seattle, WA 98104

Ruth Shnider
URS Company
4th & Vine Bldg.
Seattle, WA 98121

Kent Short
National Weather Service
1700 Westlake N. Rm. 728
Seattle, WA 98109

Chris Smith
Shorelines Hearings Board
#1 South Sound Center
Lacey, WA 98504

Mike Smith
City of Tacoma
Rm. 335 County-City Bldg.
Tacoma, WA 98402

R.N. Steele
Pacific Coast Oyster Growers Assn.
239 Chuckanut
Blanchard, WA 98232

Carol Stephenson
N.W. Pulp and Paper
555 116th N.E.
Bellevue, WA 98004

Susan Sugai
Laboratory Radiation Ecology
University of Washington WH-10
Seattle, WA 98195

Robert G. Swartz
METRO
410 W. Harrison
Seattle, WA 98119

Bruce Thelen
NOAA
1801 Fairview E.
Seattle, WA 98102

Ron Thom
College of Fisheries
University of Washington WH-10
Seattle, WA 98195

Nancy Thomas
Washington Environmental Council
107 S. Main
Seattle, WA 98104

Thornton Thomas
Trust for Public Land
P.O. Box 216
Bellevue, WA 98009

Richard D. Tomlinson
METRO
410 W. Harrison
Seattle, WA 98119

Richard W. Tyler
University of Washington
6215 N.E. 153rd
Bothell, WA 98011

James A. Vaupel
Olympia School District
Capital High School
2707 Conger
Olympia, WA 98502

Marvin Vialle
Washington Dept. of Ecology
Olympia, WA 98504

Ronald E. Westley
Washington Dept. of Fisheries
Box 600 Pt. Whitney Rd.
Brinnon, WA 98320

Cecil M. Whitmore
METRO
600 First
Seattle, WA 98104

Cecil Wingert
College of Fisheries
University of Washington WH-10
Seattle, WA 98195

Roger Wolcott
U.S. Fish & Wildlife Service
2625 Parkmont Bldg. A
Olympia, WA 98502

John R. Yearsley
EPA Region X
1200 Sixth Ave.
Seattle, WA 98101

Jon Young
Oceanographic Inst. of Washington
312 First N.
Seattle, WA 98109

George Yount
21625 92nd W.
Edmonds, WA 98020